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IN MEMORIAM: OSCAR ELTON SETTE

Oscar Elton Sette died on July 25, 1972, at Palo Alto, Calif. He was 72. On September 7th his ashes were scattered at sea from the research vessel *David Starr Jordan*.

The last issue of this journal (*Fishery Bulletin*, Vol. 70, No. 3) was dedicated to Elton Sette. His colleagues who contributed papers to that thick number make up a roster of some of the most able scientists in the field of marine research today, yet it was woefully incomplete, because many who had wished to contribute were unable to do so. The number had been planned by his friends as a surprise gift to Elton (but how it would have benefited from his quick editorial eye!): it must now stand as a memorial.

Towards mid-July, Phil Roedel, Director of the National Marine Fisheries Service, wisely broke the 2 years of secrecy surrounding the "Sette number" and sent Elton the table of contents and a copy of Pat Powell's warm portrait. Elton was pleased.

Since July 1970, Elton had been a member of the Editorial Committee of the *Fishery Bulletin*. This is the first number not to carry his name. Assuredly, it will not be the last to show his influence on the course of marine research. We had planned a gift to him: he left one to us — a standard of high and unflagging professional competence. Not many men leave as much.

Reuben Lasker
Scientific Editor

Thomas A. Manar
Chief, Scientific Publications Staff

TEMPERATURE AND PHYTOPLANKTON GROWTH IN THE SEA

RICHARD W. EPPLEY[1]

ABSTRACT

The variation in growth rate with temperature of unicellular algae suggests that an equation can be written to describe the maximum expected growth rate for temperatures less than 40°C. Measured rates of phytoplankton growth in the sea and in lakes are reviewed and compared with maximum expected rates. The assimilation number (i.e., rate of photosynthetic carbon assimilation per weight of chlorophyll *a*) for phytoplankton photosynthesis is related to the growth rate and the carbon/chlorophyll *a* ratio in the phytoplankton. Since maximum expected growth rate can be estimated from temperature, the maximum expected assimilation number can also be estimated if the carbon/chlorophyll *a* ratio in the phytoplankton crop is known.

Many investigations of phytoplankton photosynthesis in the ocean have included measures of the assimilation number, while fewer data are available on growth rate. Assimilation numbers for Antarctic seas are low as would be expected from the low ambient temperatures. Tropical seas and temperate waters in summer often show low assimilation numbers as a result of low ambient nutrient concentrations. However, coastal estuaries with rapid nutrient regeneration processes show seasonal variations in the assimilation number with temperature which agree well with expectation.

The variation in maximum expected growth rate with temperature seems a logical starting point for modeling phytoplankton growth and photosynthesis in the sea.

Temperature does not seem to be very important in the production of phytoplankton in the sea. For example, Steemann Nielsen (1960) has written, "Recent investigations have shown, however, that the direct influence of temperature on organic production in the sea is fairly insignificant." Other reviewers of photosynthesis in the sea likewise give little or no consideration to a role of temperature and Steemann Nielsen's statements find widespread endorsement in the published data on geographic and seasonal variation in marine phytoplankton photosynthesis.

In response to this, the reader may ask at least two questions: (1) Why is temperature of so little importance and (2) why would anybody write a review on temperature and phytoplankton growth in the oceans? Several answers to the first question have appeared in the literature and some of these will be discussed in this account. I have two answers for the second question. The purpose of this review is (1) to suggest maximum growth and photosynthetic rates which might be reasonably expected for natural marine phytoplankton and (2) to point out the interrelationship among growth rate, photosynthetic assimilation number (i.e., rate/chlorophyll), and carbon/chlorophyll *a* ratios in the phytoplankton.

What follows is an attempt to show that temperature sets an upper limit on phytoplankton growth rate and on the rate of photosynthesis per weight of chlorophyll, and that this upper limit can be predicted from a knowledge of temperature and the carbon and chlorophyll content of the plants.

It can perhaps be inferred, from above, that phytoplankton growth in the oceans seldom approaches the upper limits imposed by the temperature of the water and that temperature does not figure prominently in simulation models for primary production in the marine environment. Other factors effect reduced rates of growth and

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photosynthesis and diminish the potential production of phytoplankton. Nevertheless, earlier reviewers have been able to generalize on several aspects of the relation between phytoplankton growth and temperature (see especially Talling, 1957; Steemann Nielsen, 1960; Ichimura and Aruga, 1964; Yentsch and Lee, 1966; Ichimura, 1968). Culture experiments have revealed that clones of a species isolated from cold or warm seas may differ in their optimum temperature for growth (Braarud, 1961; Hulburt and Guillard, 1968).

VARIATION IN SPECIFIC GROWTH RATE (μ) WITH TEMPERATURE IN LABORATORY CULTURES OF UNICELLULAR ALGAE

Much of the available data on the specific growth rates of algae in culture have been assembled by Hoogenhout and Amesz (1965). Growth rates for marine phytoplankton fall in the same range of values as those for freshwater algae, and there are no obvious distinctions between marine and freshwater unicellular algae with respect to the variation of specific growth rate (μ) with temperature. Hence data for algae from the two media will not be segregated.

Specific growth rate is defined as the rate of increase of cell substance per unit cell substance $1/N\ dN/dt = \mu$. Since dN/dt depends upon the rate of metabolic processes, one expects some temperature variation of μ if conditions are otherwise favorable for growth (i.e., if light and nutrient supply are not growth-rate limiting). This variation can be seen in Figure 1. Data of Figure 1 were selected from Hoogenhout and Amesz (1965) as representing, as nearly as possible, growth rates measured under conditions such that temperature would be rate limiting. Figure 1 shows much variation in μ among species at a given temperature. Most of this results from differences in cell size (Williams, 1964; Eppley and Sloan, 1966; Werner, 1970) and in the concentration of photosynthetic pigments within the cells of the different species (Eppley and Sloan, 1966).

It has been mechanically impossible to identify each of the points on the Figure by species (approximately 130 species or clones were included, some for several temperatures). No doubt, by further literature search, the entire area beneath the line of maximum expected growth rate could be filled in. It is perhaps surprising and a tribute to the quality of the measurements from many laboratories that only three of nearly 200 values were rejected as being unrealistically high. Inclusion of these three spurious values would only be an embarrassment to the authors rather than a critique of the validity of the line of maximum expected growth rate presented.

Not plotted in Figure 1 are values of μ for *Chlamydomonas mundana* photoassimilating acetate (Eppley and Macias R., 1962), *Chlorella pyrenoidosa* 7-11-05 for which μ was computed for increase in cell substance uncoupled from cell division (Sorokin and Krauss, 1962), or for the photosynthetic bacteria listed by Hoogenhout and Amesz (1965). Values for these slightly exceed the line of maximum expected μ. Figure 1 is limited to algae growing photoautotrophically with carbon dioxide and water.

Two general trends are noted in Figure 1: (1) There is a gradual and exponential increase in μ with temperature up to about 40°C. Temperature data above 40°C, obtained with thermophilic, blue-green algae show no further increase in μ (Castenholz, 1969). Such temperatures are outside the range encountered in the ocean and will not be further discussed. (2) Values of μ below 40°C seem to fall within an envelope and it is possible to draw a smooth curve, i.e., a line of maximum expected value, to describe the upper limit of μ to be expected at a given temperature. An approximate equation for this line is:

$$\log_{10} \mu = 0.0275T - 0.070 \qquad (1)$$

where T is temperature in degrees Celsius.

Equation (1) gives a Q_{10} for growth rate of 1.88, slightly lower than expected from the Q_{10} for photosynthesis measured in natural waters (Talling, 1955, gives $Q_{10} = 2.3$; Williams and Murdoch, 1966, give $Q_{10} = 2.25$; Ichimura, 1968, gives $Q_{10} = 2.1$) or the Q_{10} for growth rate of laboratory cultures suggested earlier (Eppley and Sloan, 1966, give $Q_{10} = 2.3$).

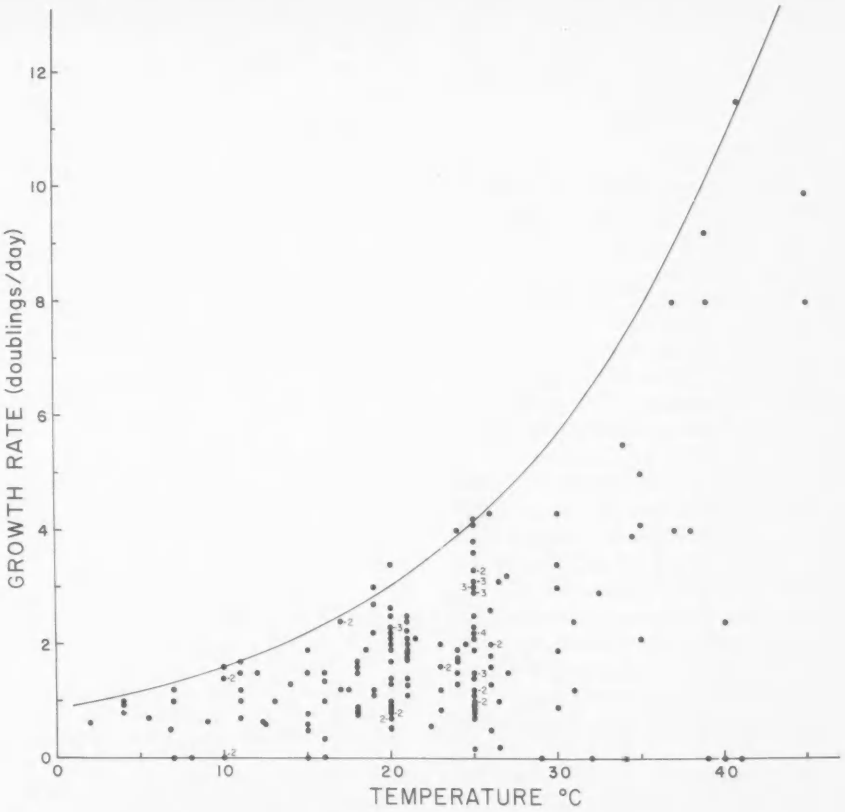

FIGURE 1.—Variation in the specific growth rate (μ) of photoautotrophic unicellular algae with temperature. Data are all for laboratory cultures. Growth rate is expressed in doublings/day. Approximately 80 of the points are from the compilation of Hoogenhout and Amesz (1965). That listing is restricted to maximum growth rates observed, largely in continuous light. The figure also includes additional data, mostly for cultures of marine phytoplankton, from the following sources: Lanskaya (1961), Eppley (1963), Castenholz (1964, 1969), Eppley and Sloan (1966), Swift and Taylor (1966), Thomas (1966), Paasche (1967, 1968), Hulburt and Guillard (1968), Jørgensen (1968), Smayda (1969), Bunt and Lee (1970), Guillard and Myklestad (1970), Ignatiades and Smayda (1970), Polikarpov and Tokareva (1970). The latter papers include about 50 strains of marine phytoplankton. The line is the growth rate predicted by Equation (1), i.e., the line of maximum expected μ. Small numbers by points indicate the number of values which fell on the point.

I will avoid speculation on possible reasons why such a curve would include algae from a wide variety of taxonomic groups, including both eucaryotic and procaryotic cell types, cells with different complements of photosynthetic pigments, and diverse morphologies. Nevertheless, the curve and Equation (1) appear to be useful as a generalization of maximum μ to be expected for photosynthetic unicellular algae.

Equation (1) is essentially a van't Hoff formula and can be expressed in the more typical form

$$\mu = 0.851\ (1.066)^{T}. \qquad (1a)$$

McLaren (1963) discussed the choice of a temperature function and preferred the formula of Bělehrádek

$$\mu = a\ (T - \alpha)^{b} \qquad (1b)$$

where a, b, and α are constants. A virtue of this equation, among the three monotonic functions discussed by McLaren (1963) is that α, the scale positioning factor, represents a "biological zero" for the process. A graph of log (μ) vs. log ($T - \alpha$) assumes linearity for appropriate values of α. Fitting values from Equation (1) at $T = 0$, 10, 20, and 30 degrees gave linear graphs if α were $\leqslant -40$ degrees. For $\alpha = -40$, a and b were approximately 2.46×10^{-6} and 3.45, respectively.

Figure 1 can be made more understandable by comparing μ vs. temperature curves for a few selected species for which fairly complete data are available (Figure 2). Each of these species has a different optimum temperature and the maximum growth rate for each approaches the line of maximum expectation. Such "μ vs. temperature" curves typically show a gradual diminution of μ as temperature decreases from the optimum, but an abrupt decline at supraoptimal temperatures.

Temperature optima and the upper critical temperature can be shifted somewhat by altering environmental conditions. For example, the salinity of the culture medium influences these parameters in euryhaline *Dunaliella tertiolecta* (Figure 3). Note, however, that only one salt concentration gives the unique maximum growth rate of about 5.0 doublings/day.

The figures can be criticized as being limited with respect to the number of species included. Furthermore many of them represent "laboratory weed" species and relatively few are ecologically significant ocean phytoplankton. Happily this shortcoming is temporary and information on important planktonic species is growing (see Figure 1 legend).

Use of Figures 1 and 2 or Equation (1) for insight as to maximum expected values of μ in the sea presumes that natural marine phytoplankton are autotrophic. But it is conceivable,

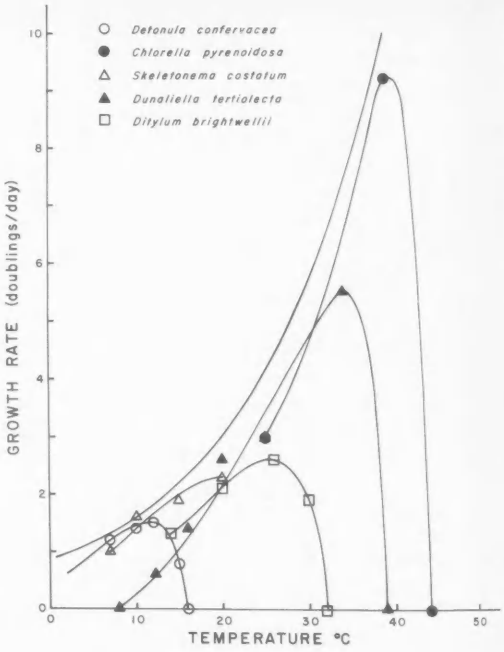

FIGURE 2.—Growth rate vs. temperature curves for five unicellular algae with different temperature optima: *Detonula confervacea* (Guillard and Ryther, 1962; Smayda, 1969), *Skeletonema costatum* (Jørgensen, 1968), *Ditylum brightwellii* (Paasche, 1968), *Dunaliella tertiolecta* (McLachlan, 1960; Ukeles, 1961; Eppley, 1963; Eppley and Sloan, 1966), *Chlorella pyrenoidosa* (Sorokin and Krauss, 1958, 1962).

although perhaps unlikely in the sea, that heterotrophic nutrition might lead to values of μ higher than predicted above, as appears to be the case when one compares doubling times of heterotrophic and photosynthetic bacteria or autotrophic vs. photoheterotrophic growth rates of the sewage alga *Chlamydomonas mundana*.

Equation (1) has been useful in this laboratory for predicting the maximum dilution rates ("washout rates") for continuous cultures. In the few organisms examined here the value of μ at washout was slightly higher than the maximum rate observed in batch cultures of the organism, but within the envelope of values predicted by Equation (1).

Rates of growth given by Equation (1) are much higher than those which permit the operation of mass cultures at maximum efficiency of light utilization or nutrient removal. Maximum production will be achieved when the product of μ and standing stock is a maximum, and light is likely to be limiting growth at some depth in the culture under these conditions (see, for example, Ketchum, Lillick, and Redfield, 1949; Myers and Graham, 1959).

The data of Figures 1 and 2 apply to cultures grown with continuous illumination (or with optimum daylength for those in which μ passes through a maximum at intermediate daylength [Castenholz, 1964; Paasche, 1968]). This lessens the utility of the data for predictive purposes with natural phytoplankton exposed to seasonally varying daylength since the daylength for maximum μ varies among species (Table 1). Efforts to generalize on the influence of daylength on μ have not been very successful since the daylength allowing maximum μ at a given temperature seems to vary with the intensity of illumination (Tamiya et al. 1955; Terborgh and Thimann, 1964). A proportion between μ and the number of hours of light/24 hr is often assumed but this can be only a first approximation.

TABLE 1.—Daylength resulting in maximum growth rate for some algae which show depressed growth rate in continuous light. Some species which showed maximum μ in 24 hr light/day are shown for comparison.

Organism	Day-length (hr)	Growth rate[1] μ_{max}	Temper-ature (°C)	Reference
Ditylum brightwellii	16	2.1	20	Paasche (1968)
Nitzschia turgidula	16-24	2.5	20	Paasche (1968)
Fragilaria sp.	24	1.7	11	Castenholz (1964)
Biddulphia sp.	15	1.5	11	Castenholz (1964)
Synedra sp.	15-24	1.2	11	Castenholz (1964)
Melosira sp.	15-24	0.7	11	Castenholz (1964)

[1] Units are doublings/day.

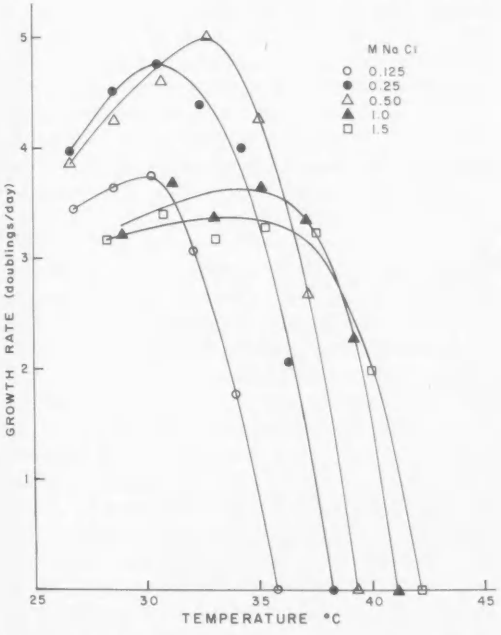

FIGURE 3.—Growth rate vs. temperature curves for *Dunaliella tertiolecta* measured in culture media containing different salt concentrations (R. W. Eppley and F. M. Macias, unpublished data).

Use of Figure 1 and Equation (1) for insight on the behavior of natural phytoplankton requires the further assumption that the organisms present are reasonably adapted to ambient temperatures and are, preferably, at a temperature somewhat less than optimum. Aruga (1965a) has shown this to be so for the phytoplankton of a pond on the University of Tokyo campus. Smayda (1969) has discussed his own and earlier observations on the distribution of phytoplankton in nature where temperature optima for growth in laboratory cultures were invariably higher by several degrees than the water temperature in which the species flourish.

Figure 2 suggests that μ for suboptimal temperatures will be only slightly lower than would be predicted from the maximum μ for the species given a temperature coefficient (Q_{10}) for growth of about 2. However, some organisms show a critical lower temperature, above the freezing point of water, below which no growth occurs. Ukeles (1961) has listed such lower critical temperatures for several species, and see Smayda (1969) for another example. Temperatures in excess of the optimum for growth result in a much steeper decline in μ with increasing temperature than do suboptimal temperatures; growth in this thermal region would be risky

if the ambient temperature were subject to fluctuations of a few degrees.

ESTIMATES OF THE SPECIFIC GROWTH RATES OF PHYTOPLANKTON IN THE SEA

REVIEW OF METHODS

Measurement of the phytoplankton specific growth rate in nature is not a routine procedure both because of the lack of widely accepted methodology and because the utility of such data is not well appreciated. J.W.G. Lund, J. F. Talling, L. A. Lanskaya, T. J. Smayda, J. D. H. Strickland, and S. Ichimura and his colleagues have been the pioneers in such measurement in natural waters while R. W. Krauss and J. Myers have promoted the measurement of μ for laboratory cultures.

Minimal values of μ can be calculated from rates of increase of cell concentration or of chlorophyll during the spring bloom in temperate waters, although advection, diffusion, and grazing complicate their interpretation. Recent examples of this technique are provided by Bunt and Lee (1970), Pechlaner (1970), and Happey (1970). Samples of water can also be incubated in bottles for cell counting at intervals (see, for example, Talling, 1955; Smayda, 1957). In oligotrophic waters the period of growth necessary to allow a precise estimation is likely to result in the depletion of nutrients and the gradual diminution of μ with time. In rich water if growth were extensive, changes in μ would be expected as a result of the decrease in effective illumination in the bottles due to self-shading. Short-term incubations of less than 24 hr may be complicated by diel periodicity in the property measured, by synchronous cell division, or insufficient change for meaningful calculations. Such problems are eased in shipboard cultures provided with adequate nutrients for growth, but here rates may be unreasonably high if ambient nutrient or light levels in the natural water are not duplicated.

Estimates of μ are obtained routinely in terms of ^{15}N-nitrogen assimilation rate per unit particulate nitrogen in the sample, but such rates will underestimate μ to the extent that the particulate nitrogen analyzed includes detrital and other nonphytoplankton nitrogen (Dugdale and Goering, 1967).

Carbon assimilation rates per unit phytoplankton carbon have also been calculated but suffer from the errors inherent in measuring the latter as well as from the uncertain reality of incubation conditions (Riley, Stommel, and Bumpus, 1949; McAllister, Parsons, and Strickland, 1960; McAllister et al., 1961; Antia et al., 1963; McAllister, Shah, and Strickland, 1964; Strickland, Holm-Hansen, Eppley, and Linn, 1969). What is needed is an instantaneous method not confounded by the complexities of long incubation either in situ, in enclosed vessels, or in shipboard cultures. Unfortunately, no such method is in view.

In this laboratory two methods have been employed for estimating the carbon content of the crop. In the first of these, all the cells in the sample are counted and their dimensions measured so that the cell volume of each species can be calculated (see Kovala and Larrance, 1966, for dealing with cell shape problems). The carbon content of a cell is then computed from its volume, or "plasma volume," using empirical equations developed from laboratory culture (Mullin, Sloan, and Eppley, 1966; Strathmann, 1967). The carbon in each species is then obtained from the concentration of cells of that species, and the total carbon of all species is summed. Several applications of this method have been published (Strickland, Eppley, and Rojas de Mendiola, 1969; Holm-Hansen, 1969; Eppley, Reid, and Strickland, 1970; Reid, Fuglister, and Jordan, 1970; Zeitzschel, 1970; Beers et al., 1971; Hobson, 1971; Eppley et al., in press). In the second method, only recently put into practice, the adenosine triphosphate (ATP) content of particulate matter retained on a fine porosity filter is determined (Holm-Hansen and Booth, 1966). The ATP is apparently restricted to living cells but may include contributions from bacteria, protozoans, and other colorless microorganisms, as well as phytoplankton, even if larger animals are removed by passing the sample through netting. However, phytoplankton appear to be predominant in water samples from

the euphotic zone judged from the rough proportionality of ATP to chlorophyll. Estimates derived from ATP appear to agree well with those given by the first method (Holm-Hansen, 1969) and the ratio C/ATP approximates 250.

In determining an average μ for the phytoplankton the carbon content, as measured above, is taken at the beginning of the photosynthesis measurement to give phytoplankton carbon at time zero (C_0). The measured daily rate of photosynthetic carbon assimilation, assumed to represent net carbon assimilation (ΔC), is then added to the carbon content after a day's growth. The specific growth rate is then calculated as:

$$\mu = \frac{1}{t} \log_2 \left(\frac{C_0 + \Delta C}{C_0}\right) \qquad (2)$$

to give μ in doublings of cell carbon per day.

It should be straightforward to compute μ using ATP determined initially and after 24-hr incubation, and this has been done at least once (Sutcliffe, Sheldon, and Prakash, 1970). We have used chlorophyll *a* values, before and after 24- or 48-hr incubation, to compute μ but the results were poor due to the plasticity of cell chlorophyll *a* content and the difficulty of providing incubation conditions sufficiently close to those in nature to maintain constant cell chlorophyll *a* per cell or per weight of carbon (Eppley, 1968).

Increase in the total volume of particulate matter, determined with an electronic particle counting and sizing machine, can also be used to compute μ (Parsons, 1965; Cushing and Nicholson, 1966; Sheldon and Parsons, 1967). This method holds much promise when changes are large enough to be significant over background levels of particulates. The cost of the machines is a serious drawback to wider use, and the problems in proper incubation of the sample to mimic conditions in the sea are as serious here as in the other incubation methods.

Sweeney and Hastings (1958) used the percentage of paired dinoflagellate cells in cultures as a measure of the time of day of cell division and this has been used at sea (R. Doyle, Duke University, personal communication). A variation on this theme has allowed estimates of μ for *Pyrocystis* species in situ (E. Swift, University of Rhode Island, personal communication). Changes in cell morphology related to cell division probably give the least ambiguous estimates of μ where advection and sinking are not serious problems and when a parcel of water can be followed over time. The time course of change in valve diameter in diatoms seems to be out of favor for estimating μ since valve diameter in cultures may not decrease in a regular way or always be proportional to the number of cell divisions. Methods of measuring microbial growth rates were recently reviewed by Brock (1971).

RESULTS OF GROWTH RATE MEASUREMENTS IN THE NATURAL PHYTOPLANKTON AT DIFFERENT TEMPERATURES

In their classic paper of 1949, Riley, Stommel, and Bumpus expressed photosynthetic rate as the daily carbon assimilation per unit plant carbon, a measure readily calculated as μ in doublings/day. They used Baly's equation as a model. This equation includes temperature as a variable influencing photosynthetic rate. The constants in the equation were computed from Baly's compilation of data on *Chlorella* cultures and detached leaves, and from Jenkin's 1937 data for a culture of *Coscinodiscus* incubated at various depths in the sea. I have calculated expected values of μ using their Equation 6 for different levels of total incident radiation (Figure 4). It is seen that the Baly equation is relatively insensitive to temperature, in comparison to Figure 1, and gives values inconsistent with the results from laboratory cultures.

Bunt and Lee (1970) provide a unique set of data on the photosynthetic rates of Antarctic phytoplankton which grow under the ice layer, an environment with low ambient light and with temperature approximately —2°C. They also provide seasonal values of the particulate carbon and chlorophyll *a* concentration. A maximum, midsummer, value of μ was less than 0.5 doublings of cell carbon/day.

Most of the data which allow estimates of μ are from nutrient-poor waters, such as are found

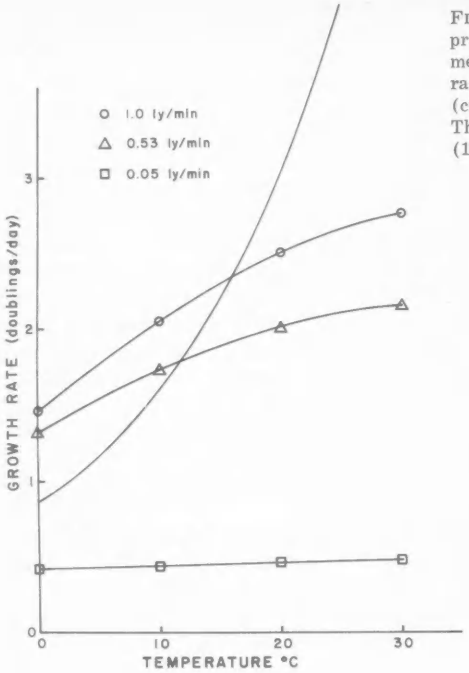

FIGURE 4.—Growth rate vs. temperature relationship predicted by the Baly equation as used by Riley, Stommel, and Bumpus (1949). Three different levels of total radiant energy are included for the Baly equation: 1.0 (circles), 0.53 (triangles), and 0.05 ly/min (squares). The line of maximum expectation predicted by Equation (1) is drawn for comparison (no symbols).

in the Sargasso Sea, the Eastern Tropical Pacific, and southern California coastal waters. Exceptions are μ estimates obtained from upwelling regions off Peru (Strickland, Eppley, and Rojas de Mendiola, 1969; Beers et al., 1971) and southwest Africa (Hobson, 1971) where nutrient limitation is not a factor reducing μ.

A summary of estimated values of μ, as average doublings of cell carbon/day in the euphotic zone, is provided in Table 2. The recent data are based upon simulated in situ techniques usually involving 24-hr incubation in order to obtain photosynthetic rates free of errors resulting from diel periodicity in metabolism. The list of values given is not inclusive but is, hopefully, representative. Mean values of μ in the Peru Current showed little variation and averaged about 0.7 doubling/day. Values of this magnitude are consistent also with estimates from ^{15}N-labeled nitrate assimilation rates measured by R. C. Dugdale, J. J. Goering, and

TABLE 2.—Some estimates of the average specific growth rate of phytoplankton in the euphotic zone for various regions. Temperatures indicated are for the surface or the average in the mixed layer.

Location	Temperature (°C)	Growth rate as doublings/day		Reference
		Measured	Max. expected	
Oligotrophic waters				
Sargasso Sea	--	0.26	--	Riley, Stommel, and Bumpus (1949)
Florida Strait	--	0.45	--	Riley, Stommel, and Bumpus (1949)
Off the Carolinas	--	0.37	--	Riley, Stommel, and Bumpus (1949)
Off Montauk Pt.	--	0.35	--	Riley, Stommel, and Bumpus (1949)
Off southern California				
July 1970	20	0.25-0.4	1.5	Eppley et al. (in press)
Apr.-Sept. 1967	12-21	0.7 avg	0.9-1.6	Eppley et al. (1970)
Nutrient-rich waters				
Peru Current				
Apr. 1966	17-20	0.67 avg	1.5	Strickland, Eppley, and Rojas de Mendiola (1969)
June 1969	18-19	0.73 avg	1.4	Beers et al. (1971)
Off S.W. Africa	--	1.0 avg	--	Calculated from Hobson (1971)
Western Arabian Sea	27-28	>1.0 avg	2.4	Calculated from Ryther and Menzel (1965b)

[1] From Equation (1) assuming μ will be one-half the value calculated as expected if daylength is 12 hr and μ is directly proportional to the number of hours of light per day.

co-workers (University of Washington, 1970) in the Peru upwelling region.

The maximum values of μ observed in depth profiles off Peru approached those expected from Figure 1 if the effect of daylength is considered (Figure 5) but were lower as a result of low insolation brought about by continuous cloud cover. Depth profiles of μ roughly parallel those for photosynthetic rate per weight of chlorophyll *a* and both show diminished rates with depth as a result of decreasing light.

Figure 5 also shows a depth profile of μ for the North Central Pacific where μ was depressed because of low ambient nutrient concentrations. Enrichment experiments suggested that growth rate was limited at two stations by low concentrations of both nitrogen and phosphorus and at a third station by nitrogen alone (Perry, in press).

Thomas (1970b) and Thomas and Owen (1971) reported values of μ for 10 m depths in the eastern tropical Pacific Ocean. In situ μ was estimated to be about 0.2 doubling/day resulting from low ambient nitrogen concentration. Shipboard cultures were enriched with various concentrations of nitrogen (nitrate and ammonium), and the variation of μ with nitrogen concentration was determined (Thomas, 1970b). Maximum values of μ were 1.1-1.5 doublings/day.

In many cases nutrient limitation (in the upper surface waters) or light limitation (in deeper waters and in nonstratified water where vertical mixing may reduce the effective light level to which the phytoplankton are exposed) appears to decrease μ. The values expected from Figure 1 are not realized under such conditions and μ shows little or no temperature-dependence.

Table 3 presents growth rates measured by three different methods (i.e., from the velocity of nitrogen assimilation per unit particulate nitrogen, from the photosynthetic carbon assimilation rate per unit phytoplankton carbon, where the carbon content of the phytoplankton crop was determined from ATP, and from cell concentration and cell volume). Growth rates from the three methods usually agree within a factor of two, but more precise methods are desirable. The value from ^{15}N assimilation rate

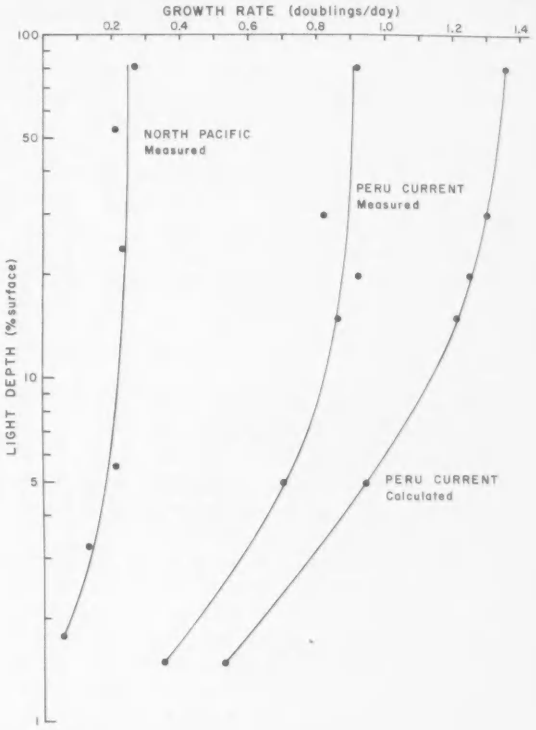

FIGURE 5.—Variation in growth rate of natural marine phytoplankton with depth in the Peru Current, June 1969, and in the subtropical North Pacific central gyre, November 1971 (this laboratory, unpublished). The "light depth" of the ordinate was calculated as the radiant energy at depth as a percentage of that at the surface so that data from the two regions, with euphotic zone depths of about 30 and about 150 m, could be compared. The calculated line is based on Equation (1) for 19°C with the assumption that light limits growth rate below the surface. The μ_{max} from Equation (1) was multiplied by $(I/2.5 + I)$ where I is the radiant energy at depth as percent of surface. The half-saturation constant of 2.5% is low (see Rodhe, 1965) and suggests that the Peru Current phytoplankton were "shade adapted." Hence, measured μ would be less than expected from Equation (1), in spite of abundant nutrients. In the North Pacific study enrichment experiments and other data suggested limitation of phytoplankton growth rate by both nitrogen and phosphorus concentration (Perry, Renger, Eppley, and Venrick, unpublished data). There the temperature in the mixed layer was 22°C and the maximum expected value would be slightly greater than shown for the Peru Current.

TABLE 3.—Some comparison of the average growth rate of phytoplankton in the euphotic zone in southern California coastal waters using different methods of estimation.

Month	Station	Photosynthetic rate (g C/m²/day)	Standing stock From ATP (g C/m²)	Standing stock From cell vol. (g C/m²)	Growth rate (doubling/day) by method (a)	(b)	(c)
June 1970	4	0.53	2.4	2.0	0.28	0.33	0.13
	7	1.05	3.1	3.25	0.42	0.40	--
July 1970	1	1.37	8.4	--	0.26	--	0.19
	6	1.10	4.4	--	0.32	--	0.22
	10	0.36	3.6	--	0.13	--	0.21
	19	1.76	5.9	5.38	0.37	0.40	0.15

[1] Methods: (a) μ from photosynthetic rate and ATP × 250 = standing stock as carbon.
(b) μ from photosynthetic rate and standing stock carbon computed from cell numbers and cell volumes.
(c) μ computed from assimilation rate of nitrate + ammonium + urea per unit particulate nitrogen. Data for method (c) from McCarthy (1971) and Institute of Marine Resources (1972, see text footnote 2). Other data are unpublished values from this laboratory. Surface water temperatures were 18°-20°C. Maximum expected growth rates would be about 1.5 doublings/day.

tends to be lower than those from ^{14}C assimilation rate because no correction was made for the detrital nitrogen in the particulate matter, while detrital carbon is not a complication in the other methods. Low growth rates in these samples resulted from nitrogen limitation.

Rates of nitrogen assimilation per weight of particulate N were measured in the Sargasso Sea and Peru upwelling regions (Dugdale and Goering, 1967; Dugdale and MacIsaac, 1971), and in the eastern tropical Pacific Ocean (Goering, Wallen, and Nauman, 1970) which allow estimates of μ.

As is readily seen from the above discussion and the values of Tables 2 and 3 we have very little data at hand to properly evaluate the role of temperature in determining maximum rates of phytoplankton growth in the sea, and whether Figures 1 and 2 and Equation (1) are useful guides for field work. It is hoped that this lack will stimulate more effort to make growth rate measurements. Most needed are μ values for cold waters and warm, nutrient-rich waters.

Meantime let us turn to lakes and ponds. Additional growth rate data are available and the influence of temperature on growth rate is often apparent. Since growth rates seem comparable in laboratory cultures for freshwater and marine unicellular algae, as noted earlier, μ vs. temperature in lakes should be of equal interest to limnology and oceanography. Some data are given in Table 4 which confirm low μ values in cold water and a variation in μ with temperature in outdoor ponds.

The phytoplankton growth rates in lakes which show a variation in μ with temperature were usually measured in the spring as the waters were gradually warming but before nutrients were depleted to levels limiting to the rate of phytoplankton growth (cf. Cannon, Lund, and Sieminska, 1961). Presumably similar data could be gathered for nutrient-rich estuaries or for temperate, coastal sea areas where sufficient warming occurs to obtain a reasonable range of temperatures before stratification and nutrient depletion become severe. The seasonal succession of phytoplankton in coastal ocean waters has been much studied, and the change in the phytoplankton crop from predominantly diatoms to flagellates, with the onset of nutrient depletion, would be accompanied by a marked decrease in growth rate. One may judge the magnitude of change from the comparison of μ in the Peru Current with μ in the North Pacific central gyre (Figure 5).

INTERRELATION BETWEEN SPECIFIC GROWTH RATE OF PHYTOPLANKTON AND ASSIMILATION NUMBER

The specific growth rate of phytoplankton in laboratory cultures is often measured from the rate of increase in the concentration of cells in the culture when cell counts are determined over a time interval, i.e.,

$$\mu = \frac{1}{\Delta t} \log_2 \left(\frac{N_2}{N_1}\right). \qquad (3)$$

This can also be expressed as

$$\mu = \frac{1}{\Delta t} \log_2 \left(\frac{N_1 + \Delta N}{N_1}\right) \qquad (4)$$

where N_1 is the initial cell concentration, N_2 the cell concentration after an interval of time, Δt, and ΔN is $N_2 - N_1$. To determine μ from analogous carbon units one needs the initial carbon content of the phytoplankton (C_1) and either the carbon content after a time interval Δt, i.e., C_2, or a measure of carbon assimilation by the phytoplankton during the time interval, i.e., ΔC. It will be assumed that the ^{14}C method of measuring phytoplankton photosynthesis (Steemann Nielsen, 1952) in fact measures ΔC, the net increase in particulate carbon in the phytoplankton. This is indicated by several studies with laboratory cultures which include two or more independent measures of the rate of carbon assimilation by the phytoplankton cells (Antia et al., 1963; McAllister et al., 1964; Eppley and Sloan, 1965; Ryther and Menzel, 1965a; Strickland, Holm-Hansen, Eppley, and Linn, 1969). Then μ can be calculated from carbon data from Equation (2). The evaluation of μ requires a measurement of photosynthetic rate as carbon and an estimate of the carbon content of the phytoplankton at the initiation of the measurement. Direct methods for the latter are not usually suitable because of detrital carbon in natural waters and indirect methods must often serve (see earlier discussion of methods of measuring μ). A convenient way of expressing photosynthetic rate per unit phytoplankton standing stock is the "assimilation number," i.e., the rate of photosynthetic carbon assimilation per weight of chlorophyll *a*. The terms "assimilation ratio" and "photosynthetic index" are common synonyms for assimilation number. If the carbon/chlorophyll *a* ratio in the phytoplankton is known, its carbon content can, of course, be calculated from chlorophyll measurements. Usually this is not the case and considerable effort has been expended to derive such estimates (see, for example, Harris and Riley, 1956; Cushing, 1958; Wright, 1959; Steele and Baird, 1961, 1962; Lorenzen, 1968; Eppley, 1968; Zeitzschel, 1970; Hobson, 1971). An equation expressing μ (as doublings of cell carbon/day) in terms of the assimilation number per day and the carbon/chlorophyll ration of the phytoplankton can be derived from Equation (2) as

$$\mu = \frac{1}{\Delta t} \log_2 \left(\frac{\text{C/Chl. } a + \Delta\text{C/Chl. } a}{\text{C/Chl. } a}\right). \qquad (5)$$

This equation is useful in that it directly relates the assimilation number, i.e., the photosynthetic rate per weight of chlorophyll (ΔC/Chl. *a*), the carbon/chlorophyll *a* ratio of the phytoplankton

TABLE 4.—Phytoplankton growth rates in lakes and ponds.

Organism	Temperature (°C)	Growth rate as doublings/day		Reference
		Measured	Max. expected[1]	
		1-m depth only		
Asterionella formosa	5	0.8	1.2	Talling (1955)
		Average in the lake		
Stephanodiscus hantzschii	2-4	0.3	1.1	Pechlaner (1970)
Asterionella formosa	5	0.3	1.2	Happey (1970)
Stephanodiscus rotula	8	0.25	1.4	Happey (1970)
	15	0.7	2.2	Happey (1970)
		In outdoor ponds		
Chlorella ellipsoidea	7	0.15	1.3	Tamiya et al. (1955)
	15	0.65	2.2	
	25	1.4	4.1	

[1] From Equation (1).

(C/Chl. a), and μ. Figures 6 and 7 show this relationship graphically where the calculated assimilation number per day (Figure 6) or per hour (Figure 7) is graphed as a function of μ for different carbon/chlorophyll a ratios in the crop. Carbon/chlorophyll ratios of Figures 6 and 7 are typical of the Peru upwelling region (C/Chl. a 30-40) (Lorenzen, 1968; Strickland, Eppley, and Rojas de Mendiola, 1969; Beers et al., 1971) and the Western Arabian Sea (Ryther and Menzel, 1965b), or low-nutrient surface waters off southern California (90-100) (Eppley, 1968; Strickland, 1970); and of surface waters in the North Pacific central gyre (120-150) (Institute of Marine Resources, unpublished data). The marked dependence of the assimilation number upon the carbon/chlorophyll a ratio of the phytoplankton is noteworthy, although little discussed in the literature. It is interesting that assimilation numbers greater than about 15 per hour (see Figure 7) are rarely reported in the literature and one wonders whether this is because of disbelief in the validity of the data or because high μ and high C/Chl. a are somehow mutually exclusive in nature. The latter is most likely since such high assimilation rates and high μ would place extreme demands for nutrients, such as N and P, on the environment and could not long be sustained without massive nutrient input. Even at southern California sewage outfalls where high rates of nutrient input prevail we found low values for μ. These low values apparently result from the buildup of high phytoplankton crops which maintain low-nutrient levels in the surface waters such that growth rate is nitrogen-limited (Institute of Marine Resources).[2] Furthermore, high C/Chl. a ratios seem to be typical of nutrient depleted cells which grow slowly. For example, carbon/chlorophyll a ratios increased from 30 to over 150 with increasing nitrogen limitation of growth in N-limited chemostat cultures of marine phytoplankton (Thomas and Dodson, in press; Institute of Marine Resources[2]).

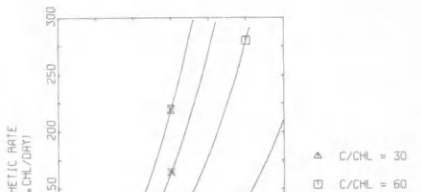

FIGURE 6.—Photosynthetic rate (assimilation number/day) vs. the specific growth rate of the phytoplankton computed from Equation (5). Photosynthetic rate is expressed as milligrams carbon assimilated per day per milligram chlorophyll a and is shown for several values of the ratio carbon/chlorophyll a in the phytoplankton crop (30, 60, 90, and 120 g/g).

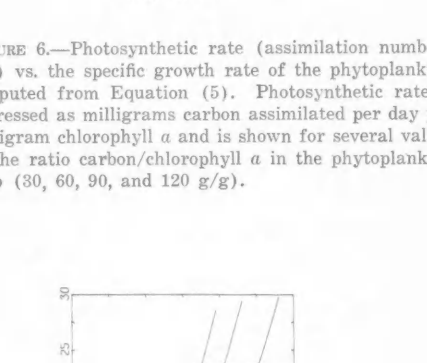

FIGURE 7.—Same as Figure 6, but photosynthetic rates (assimilation numbers) were calculated per hour, rather than per day, assuming 12 hr light per day (i.e., values of Figure 6 were divided by 12).

[2] Institute of Marine Resources. 1972. Eutrophication in coastal waters: nitrogen as a controlling factor. Final Rep. U.S. Environ. Prot. Agency, Proj. #16010 EHC. Inst. Mar. Resour., Univ. Calif., San Diego. 67 p.

THE VARIATION OF ASSIMILATION NUMBER WITH TEMPERATURE IN THE SEA

The maximum expected values of μ at different temperatures, from Equation (1), can be used to predict maximum assimilation numbers to be expected in the sea (as grams carbon/gram chlorophyll a per time). Combining Equations (1) and (5) gives rise to Figures 8 and 9 to show assimilation numbers per day and per hour for different C/Chl. a ratios in the phytoplankton. Actual rates would be lower than those shown for the reasons already discussed and would require the growth of small-celled phytoplankters with light essentially saturating for photosynthesis and with adequate nutrient concentrations. Aruga (1965b) presents graphs of assimilation numbers vs. temperature, with various light levels, for *Scenedesmus* sp. grown at 20°C. His curves resemble these in form.

The question of the influence of daylength upon μ is ignored in Figure 8 and needs further investigation before generalities may be drawn. In Figure 9 it was assumed that μ in natural phytoplankton assemblages will be one-half the value calculated from Equation (1) since that function assumes continuous light rather than natural illumination of, on the average, 12 hr light and 12 hr dark.

There are several reasons why the dramatic potential effects of temperature on assimilation number are not often observed in oceanic studies and why so little variation in assimilation numbers has been observed (cf. Ryther and Yentsch, 1958; Curl and Small, 1965). One of these is that growth at different temperatures results in shifts in the chemical composition of phytoplankton. Increased C/Chl. a ratios at low temperature would tend to increase assimilation numbers in cold waters over those predicted by Figures 8 and 9 and a constant C/Chl. a ratio cannot be assumed.

Steemann Nielsen and Jørgensen (1968a, b) point out that while the lowering of the temperature of a culture of *Skeletonema costatum* reduced the growth rate (by an amount to be expected from Figure 1 and Equation (1)), the

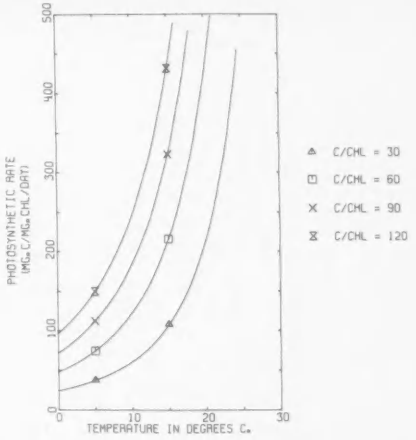

FIGURE 8.—The variation in maximum expected rate of photosynthesis (assimilation number) with temperature. Rates were computed by combining Equations (1) and (5) and are expressed as milligrams carbon/milligram chlorophyll a/day. Continuous light was assumed.

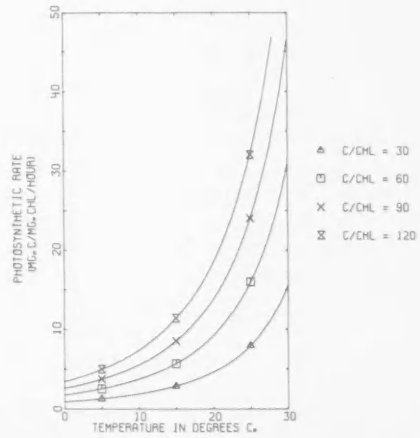

FIGURE 9.—Maximum expected photosynthetic rate (assimilation number) from Equations (1) and (5) with the assumption that the growth rate will be one-half the value predicted by Equation (1) to adjust for natural daylength averaging 12 hr light/day. Photosynthetic rates are expressed as milligrams carbon assimilated/milligram chlorophylll a/hour. This figure gives values more in line with ocean measurements than does Figure 8.

photosynthetic rate at light saturation was decreased by a lesser amount. Assimilation numbers for *S. costatum* at 2° or 8°C were higher than would be expected from Figure 9, if it were assumed that a constant C/Chl. *a* ratio was maintained at all temperatures. They observed that cells at low temperature contained greater amounts of photosynthetic enzymes and of organic matter than at higher temperatures. For example, *S. costatum* assimilated 10.2 picogram (pg) carbon/cell in one generation at 20°C, but 19.5 pg at 7°C (Jørgensen, 1968). The carbon content of a cell nearly doubled between 20° and 7°C. *Dunaliella tertiolecta* cells were likewise larger at low temperature than at high temperatures as were cells of *Ditylum brightwellii* (Table 5). This phenomenon seems to be general for mesothermal marine phytoplankton, but data for cold water species are not available. Fluctuations in C/cell and in the C/Chl. *a* are about twofold over the 10°-15°C range studied (Table 5). Steele and Baird (1962) reported high C/Chl. *a* ratios in winter in Loch Nevis and suggested that they resulted from low light "etiolation." One wonders if low winter temperatures might also play a role in this.

We have seen that low temperature reduces the assimilation number and promotes increased carbon/chlorophyll *a* ratios. Similar effects result from nutrient deficiency and were well documented by McAllister, et al. (1964). An influence of nutrient deficiency on μ was shown also in Figure 5 for the North Pacific and was noted in the eastern tropical Pacific (Thomas, 1970b). Low assimilation numbers for phytoplankton photosynthesis in nutrient-impoverished waters are well known (Curl and Small, 1965) and are clearly shown by Ichimura (1967; see his graph of assimilation number vs. phosphate concentration in the waters of Tokyo Bay). Caperon, Cattell, and Krasnick (1971) reported 10 year increases in assimilation numbers in Kaneohe Bay, Oahu, Hawaii (from approximately 6-8 to 11-13 between 1960 and 1970) which attended increased rates of waste discharge into the bay. Hepher (1962) found assimilation numbers of about 4 in unfertilized fish ponds while values in fertilized ponds averaged about 7.6. Furthermore, there are many examples of enhanced ^{14}C-assimilation rates in shipboard enrichment experiments in response to nutrient additions. A recent report is that

TABLE 5.—Carbon content of a cell and carbon/chlorophyll *a* ratios in phytoplankton cultured at different temperatures.

Organism	Carbon/cell	C/Chl./*a*	Temperature	Reference
Skeletonema costatum	19.5	--	7	Jørgensen (1968)
	16.5	--	10	Jørgensen (1968)
	12.7	--	15	Jørgensen (1968)
	10.2	--	20	Jørgensen (1968)
Ditylum brightwellii[1]	1600	41	5	Checkley (1972)[2]
	1500	48	7.5	Checkley (1972)[2]
	1330	50	10	Checkley (1972)[2]
	720	25	15	Checkley (1972)[2]
	--	20	14.5	Strickland, Holm-Hansen, Eppley, and Linn (1969)
	680	14	20	Eppley, Holmes, and Paasche (1967)
Dunaliella tertiolecta[3]	41.8	38	12	Eppley and Sloan (1966)
	35.6	29	16	Eppley and Sloan (1966)
	25.9	25	19.5	Eppley and Sloan (1966)
	28.2	24	20	Eppley and Sloan (1966)
	25.3	26	21	Eppley and Sloan (1966)
	22.5	16	25	Eppley and Sloan (1966)

[1] *D. brightwellii* was cultured with irradiance 0.05 cal/cm²/min with periodic illumination 12L : 12D by Checkley (1972, see footnote 2 below). Values are for samples at the beginning of the light period.
[2] Checkley, D. 1972. The effect of the variation of growth temperature on the ratio of carbon to chlorophyll *a* in a laboratory culture of *Ditylum brightwellii*. Univ. Calif., Inst. Mar. Resour., La Jolla, Calif. (Unpubl. manuscr.)
[3] *D. tertiolecta* was cultured under continuous light with irradiance 0.07 cal/cm²/min.

of Glooschenko and Curl (1971). These authors, and Thomas (1969, 1970a), found no enhancement in waters in upwelling regions, but assimilation numbers were increased in response to nutrient additions in oligotrophic subtropical water. Malone (1971a, b, c) found assimilation numbers in eutrophic waters to be nearly an order of magnitude greater than those in oligotrophic surface waters of the subtropical and tropical Pacific.

It has so far proved difficult to sort out the effects on assimilation number of low light and low temperature in seasonal studies of natural waters. Phytoplankton cultures grown with either low light or low temperature show low maximum photosynthetic rates per chlorophyll *a* at light saturation (P_{max}) and low saturating intensity (I_k) for photosynthesis (Talling, 1957; Steemann Nielsen and Hansen, 1959, 1961; Ichimura, 1960; Yentsch and Lee, 1966). Thus some of the effects on assimilation number usually attributed to low light levels may, in cold waters, result also from low temperature. Bunt and Lee (1970) were able to sort out the two variables in their study of diatom growth under the ice in Antarctica by comparing a station with clear ice to one with snow cover. Photosynthetic rate and growth rate were considered to be light-limited at the station with snow cover but temperature-limited at the clear ice station (see also Saijo and Sakamoto, 1964, for photosynthesis vs. depth curves in ice-free and ice-covered lakes).

Assimilation numbers in Antarctic waters are low. Many values are less than 1.0 per hour (Mandelli and Burkholder, 1966; Horne, Fogg, and Eagle, 1969; Bunt and Lee, 1970). Saijo and Kawashima (1964) found an average value of 1.2 mg C/mg Chl. *a*/hr which they attributed to low temperatures and to a deep mixed layer (resulting in a low average irradiance seen by a cell). Water temperature in these studies was usually in the range —2° to 1°C. El-Sayed and Mandelli (1965) gave a range of 1.0 to 3.6 for the assimilation number in surface samples over a temperature range —1.75° to 6.0°C. Assimilation numbers of 4-5 were found in Drake Passage and Bransfield Strait where water temperature was usually about 1°C (El-Sayed, Mandelli, and Sugimura, 1964). All these values are compatible with assimilation numbers predicted by Figure 9.

Besides shifts in carbon/chlorophyll *a* ratios with temperature and the effects of nutrient limitation and light on assimilation number there is yet another factor which tends to obscure the expected seasonal changes in assimilation number with temperature. This comes about as a result of the variation in growth rate and assimilation number with cell size. By passing a water sample through netting one can conveniently separate the phytoplankton into two size categories: the larger cells and diatom chains retained by the net (the netplankton) and the smaller cells and chains which pass through the net (the nanoplankton). Malone (1971a, b, c) has recently compared assimilation numbers of the two size fractions and cites earlier studies. Invariably, the nanoplankton showed higher assimilation numbers than the netplankton, as would be expected from laboratory studies (cited earlier) which show a regular diminution in growth rate with increasing cell size. He further showed that netplankton are relatively more abundant during upwelling in coastal waters off California (Malone, 1971b). Chain-forming diatoms seem to be characteristic of the rich waters of temperate regions during the spring bloom. Yentsch and Ryther (1959) have shown a progressive increase in the ratio nanoplankton/netplankton with seasonally increasing temperature off New England. Tropical, warm, oligotrophic waters have been shown repeatedly to contain a high proportion of nanoplankton (see references cited by Malone and by Sutcliffe et al., 1970).

The causes of such seasonal succession of phytoplankton species is one of the significant problems in the study of marine phytoplankton. One can only speculate on possible contributing factors. For example, the high (relative) sinking rates of large-celled species and long diatom chains suggest that suspension and buoyancy are more significant problems for large cells than small (Munk and Riley, 1952; Smayda, 1970). Hence stratification, reduced mixing, and the imposition of a seasonal thermocline would tend to discourage large forms. Perhaps the most ele-

gant work in such problems is that of Lund and colleagues on diatom succession in the English lakes. Artificially mixing a lake in summer, when it would normally be stratified, permitted a bloom of *Melosira italica*, a diatom which usually sinks out of the water column upon the formation of a thermocline in late spring (Lund, 1971).

Another factor which tends to select against large-celled species in low-nutrient waters results from a low surface/volume ratio and a consequent inability to absorb nutrients from low concentration (Munk and Riley, 1952). This generalization has been confirmed in laboratory experiments on the kinetics of nutrient absorption where large-celled species showed higher half-saturation constants (K_s) for nitrate and ammonium uptake than small-celled species (Eppley, Rogers, and McCarthy, 1969). Similarly, the K_s for assimilation of vitamin B_{12} by phytoplankton depends on cell size (Carlucci, 1972).[8]

The argument with respect to netplankton vs. nanoplankton and the expected seasonal changes in assimilation number with temperature can be summarized as follows: (1) Nanoplankton show higher assimilation numbers (and growth rates) than do netplankton. This generalization results both from observations of natural phytoplankton and from studies of variations with cell size in laboratory cultures. (2) Increasing insolation in the spring results in increased water temperatures, and often in stratification and seasonal thermoclines. Nutrients in the mixed layer then tend to be depleted and often rather quickly, except in very shallow water where regenerative activities of microorganisms in sediments can maintain adequate nutrient levels for rapid phytoplankton growth. (3) Stratification of the water column tends to discourage the growth of large-celled species and long chain diatoms, because (a) reduced vertical mixing may result in their sinking out of the water column and (b) they are less effective in absorbing nutrients from low ambient concentrations than are nanoplankton. (4) Both seasonal increase in temperature and in the ratio of nanoplankton/netplankton should increase assimilation numbers for photosynthesis except where growth and photosynthetic rates are reduced by nutrient limitation.

Nanoplankton would be expected to be more abundant, relative to netplankton, in oligotrophic waters because of their lower sinking rates and lower K_s values for nutrient absorption. Hence, phytoplankton of warm, oligotrophic tropical waters would be expected to show high assimilation numbers (and growth rates) except for effects of nutrient limitation. One can begin to understand from all this why a graph of assimilation number vs. temperature for observation of natural phytoplankton usually fails to show the relationship expected from Figure 9, and why so much current work emphasizes the role of nutrient concentrations in phytoplankton growth in the sea.

Some exceptional marine waters which do show the expected relationship between assimilation number and temperature are shallow coastal estuaries where nutrient regeneration on the bottom maintains a high nutrient input to the overlying water. Examples reported for the east coast of the United States are Barlow, Lorenzen, and Myren (1963), Williams and Murdoch (1966), and Mandelli et al. (1970). Both of the latter papers show graphs of assimilation number vs. temperature which match beautifully the relation expected in Figure 9. Williams and Murdoch's data fall between the C/Chl. a 30 and 60 lines, with an indication of higher C/Chl. a ratio in winter, as expected. Mandelli et al. present two graphs, one for diatoms and the other for dinoflagellates. Assimilation numbers of the latter are higher than those for diatoms and fall on the line in Figure 9 for C/Chl. $a = 30$. They also show the seasonal change in relative numbers of diatoms and dinoflagellates; the latter are more abundant at higher temperatures.

Williams and Murdoch (1966) cite several other studies which show parallels between phytoplankton production in shallow marine waters and temperature over the seasons. The Danish

[8] Carlucci, A. F. 1972. Saturation constants for vitamin assimilation by phytoplankton. (Unpubl. manuscr.)

results are reviewed also by Steemann Nielsen (1960). Few of these earlier works included chlorophyll *a* measurements, however, and assimilation numbers are not reported.

Ichimura (1967) found a close relation between temperature and assimilation number for a station well within Tokyo Bay, but not at a station in deeper water. Nutrient limitation was postulated for the outer station.

Some of the values for assimilation number and its variation with temperature which can be conveniently summarized are provided in Table 6. One might have hoped, by comparison of the data with values expected from Figure 9, to check up on the quality of one's colleagues' work and to find some reported values outside the bounds of reasonable expectation. Happily, only one of the papers reviewed gave unrealistically high assimilation numbers and these were not repeated in subsequent studies by that author.

IMPLICATIONS FOR SIMULATION MODELS OF PHYTOPLANKTON PRODUCTION

As pointed out by Patten (1968) and others, mathematical models are usually designed to be accurate or alternatively, realistic, but seldom are both. It can be seen from the preceding discussion that attempts to compute photosynthetic rates from temperature would generally be inaccurate, and unrealistic as well, unless radiant energy and concentrations of essential nutrients were also considered. In the past, models of photosynthesis have often included a term for the maximum rate of photosynthesis at light saturation which is widely acknowledged to be temperature-dependent. In Steele's (1962) model P_{max} is a constant and is expressed in units "carbon assimilation rate per unit plant carbon"

TABLE 6.—Assimilation numbers measured in different ocean regions in comparison with maximum expected values taken from Figure 9. A similar table is given by Saijo and Ichimura (1962) for pelagic and coastal seawaters and lakes.

Region	Assimilation number (mg C/mg Chl./hr)				Temperature (°C)	Source
	Measured	Max. expected if C/Chl. =				
		30	60	90		
Cold Seas						
Antarctic	avg <2.5	1.0	2.0	3.0	−2-2	(1)
Subarctic North Pacific	0.4-2	1.4	2.7	4.0	2-6	(2)
North Atlantic	3.5	1.4	2.7	4.0	4-6	(3)
	3.5	1.7	3.4	5.1	9	(3)
	4	3.1	6.3	9.4	16	(3)
Upwelling Regions						
Peru Current	<7.5	4.6	9.2		17-20	(4)
Peru Current	5	4.6	9.2		[1](20)	(5)
S.W. Africa	<6.5	4.6	9.2		[1](20)	(6)
Cromwell Current	5.3	5.1	10.3		21	(7)
	10	8.0	16.0		25	(7)
Tropical Seas						
Madagascar	avg 3.8	8.0	16.0		[1](25)	(8)
Caribbean	avg 6.3a	8.0	16.0		[1](25)	(9)
	avg 3.7b					
Tropical Pacific	avg 2.3a	8.0	16.0		[1](25)	(9)
	avg 1.5b					
Off Puerto Rico	<13	8.0	16.0		[1](25)	(10)
Western Arabian Sea	avg 4.4	11.7	23.4		<28	(11)

[1] Assumed temperature.

Sources: (1) Saijo and Kawashima, 1964; El-Sayed and Mandelli, 1965; Mandelli and Burkholder, 1966; Horne et al. 1969; Bunt and Lee, 1970; (2) Biological station, Nanaimo (1970. Biological, chemical and physical data First Canadian Trans-Pacific Oceanographic Cruise March to May 1969. Fish. Res. Board Can., Manuscr. Rep. 1080, 92 p). (3) Steemann Nielsen and Hansen, 1959, for light-saturated rate; (5) Lorenzen, 1968, average over the euphotic zone; (7) Barber and Ryther, 1969, average over the euphotic zone; (8) Sournia, 1968; (9) Malone, 1971a. Values designated by "a" are for nanoplankton, "b" values for netplankton; (10) Burkholder, Burkholder, and Almodóvar, 1967; (11) Ryther and Menzel, 1965b, average for euphotic zone.

and is equivalent to a specific growth rate of about 1.1 doublings/day. Such a value would be appropriate for temperate waters, but probably not for polar or eutrophic tropical waters. But to make P_{max} a function of temperature would probably add unnecessary complexity for modeling purposes, although it would add realism. However, the use of constant values makes the model restrictive geographically (see, for example, Parsons and Anderson's, 1970, use of the model of Steele and Menzel, 1962, for the subarctic North Pacific).

A plant physiologist would perhaps prefer to approach modeling phytoplankton growth in the sea in as physiologically realistic way as possible and to let the computer handle the complexity. But it is questionable how realistically this can now be accomplished or what insight would thereby result.

Equation (1) of this paper can be considered a model of sorts and its apparent universality is appealing. Comparing its predictions as to growth rate and assimilation number with data from natural phytoplankton shows, moreover, the magnitude of difference between potential plant growth and reality, as it is now best estimated. The gulf between real and maximum expected values shows how significant are the other environmental factors which affect phytoplankton: radiant energy, nutrient concentrations, grazing, and mixing processes. All of these parameters have been successfully treated in models since the 1940's (see Patten's summary review, 1968; Parsons, Giovando, and LeBrasseur, 1966; Dugdale and Goering, 1967).

A physiologically realistic model might begin with a relation between temperature and maximum expected growth rate, as in Eppley and Sloan (1966). In that paper the variations in growth rate among species were rationalized by including the chlorophyll concentration per unit cell volume (a parameter not readily measurable in assemblages of mixed species, but susceptible to averaging). This parameter seemed also to compensate for the sun-shade alterations of phytoplankton photosynthesis when used to calculate radiant energy absorbed by a cell's pigments. However, the problem of daylength could not be adequately handled for species which grow faster with a few hours darkness each day than in continuous light.

None of the models proposed for primary productivity simulation has attempted to treat diel periodicity in the metabolic processes of phytoplankton. Nor is the alteration of chemical composition attendant to growth with limiting concentrations of nutrients or to variations with irradiance or temperature treated.

One suspects that the simple models now available can be satisfactory for describing the major features of regional phytoplankton production. Realistic physiological models will probably remain in the "special purpose" category for the insight of those familiar enough with the subject to use them as guide to their own research. Nevertheless, it is admitted, given the current popularity of modeling, that neither the reader nor the author may be able to resist for long the temptation to combine Equation (1) with a realistic function for nutrient assimilation rate vs. ambient concentration, a function for the dependence of μ and assimilation number upon light, and a suitable function for describing effects of mixing, in line with critical depth theory, and to try it with his favorite set of oceanic data.

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COMPARATIVE STUDY OF FOOD OF SKIPJACK AND YELLOWFIN TUNAS OFF THE COAST OF WEST AFRICA[1]

ALEXANDER DRAGOVICH AND THOMAS POTTHOFF[2]

ABSTRACT

Stomach contents of 711 skipjack tuna (*Katsuwonus pelamis*) and 132 yellowfin tuna (*Thunnus albacares*) captured in 1968 by live bait and trolling off the coast of West Africa were examined. A marked taxonomic similarity was noted between the organisms in the diets of the two tunas. Frequency of occurrence, displacement volume, and numbers of each food item identified are presented for each species of tuna. Fishes, mollusks, and crustaceans were the principal foods with fishes generally dominant. The most prominent fish families were Acanthuridae, Carangidae, Dactylopteridae, Gempylidae, Gonostomatidae, Lutjanidae, Mullidae, Priacanthidae, Scombridae, Serranidae, and Trichiuridae; mollusks were chiefly cephalopods (squids), and crustaceans consisted mostly of macrozooplankton. Juvenile tunas were present in the diet of both species of tunas.

Estimates of the size of forage organisms were primarily based on displacement volumes. In the majority of observations, food organisms displaced less than 1.0 ml and the displacement volumes of stomach contents varied for skipjack tuna from 0.1 to 20.0 ml and for yellowfin tuna from 0.1 to 60.0 ml.

Spearman's rank correlation analysis was used to test for a relation between the food type (in volume and frequency of occurrence) and the lengths of skipjack and yellowfin tunas. Significant correlations were noted between the size of skipjack tuna and both the volume and the frequency of occurrence of forage fish.

A comparison between the findings of our study and that of other food studies off the coast of West Africa showed greater taxonomic similarity in tuna forage when the studies were made in the same general area and that only several types of food were of primary importance in each given area. Seasonal changes in taxonomic composition of forage organisms were also discussed.

The method used to evaluate food organisms consisted of ranking the organisms according to their dispersal indices, abundance indices, and biomass contribution. Stomatopods, the amphipod *Phrosina semilunata*, Teuthoidea, Carangidae, Serranidae, and megalopal stages were most important constituents of food throughout the investigation area.

The principal surface tuna fishery in the tropical Atlantic Ocean is located off the coast of West Africa (Jones, 1969). One of the major tasks of the Southeast Fisheries Center, Miami Laboratory, has been the study of the biology and ecology of tunas and tunalike fishes in the tropical Atlantic Ocean. In view of the recognized importance of food as an ecological factor in the life history of tunas, one project of this investigation consisted of a study of the food and feeding habits of skipjack (*Katsuwonus pelamis*) and yellowfin (*Thunnus albacares*) tunas — the two predominant species in commercial catches in those waters.

We describe and compare the food of skipjack and yellowfin tunas and discuss the relative importance of different forage organisms. We compare our findings with those of other investigators working in the same general area. This

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information may be used to study the relationship between the distribution of food organisms and occurrence of tuna schools.

Most of the information up to 1969 on food of various tunas off the west coast of Africa may be found in the review of studies of tuna food in the Atlantic Ocean by Dragovich (1969). Dragovich (1970) also reported on the food of skipjack and yellowfin tunas off the west coast of Africa.

MATERIALS AND METHODS

Samples on which the present report is based were collected during February, March, April and September, October, November of 1968 on two cruises (UN6801 and UN6802) of the research vessel *Undaunted* of the Bureau of Commercial Fisheries (now National Marine Fisheries Service) (Figure 1). All tunas sampled for

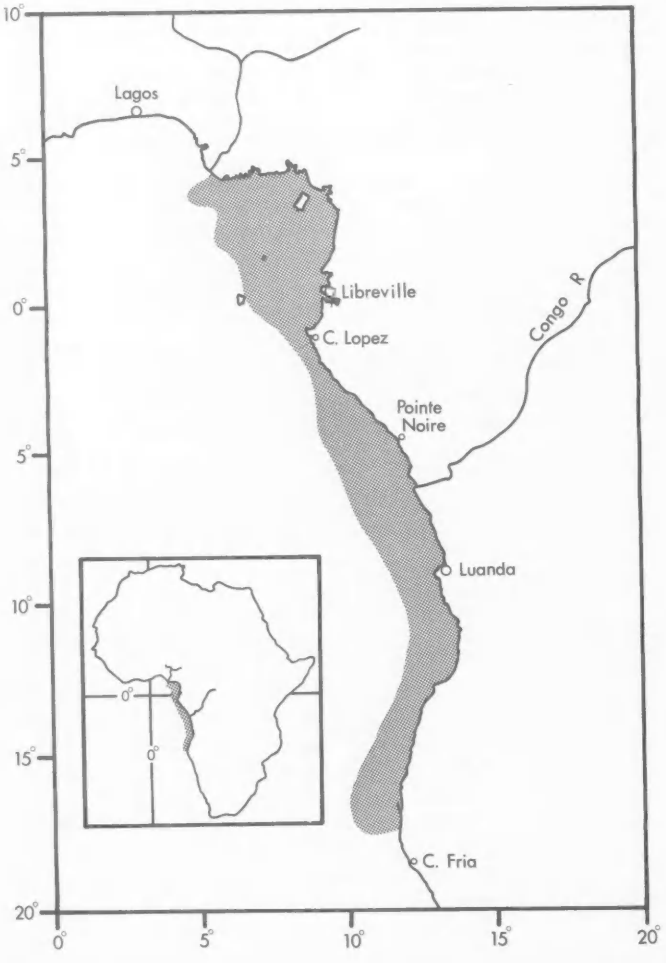

FIGURE 1.—Shaded area shows localities where stomachs of skipjack and yellowfin tunas were collected.

this study were caught by pole and line or by trolling (Table 1). A total of 711 stomachs from skipjack tuna and 132 from yellowfin tuna were examined. The skipjack tuna studied varied in fork length from 36 to 63 cm and the yellowfin tuna from 52 to 94 cm (Figure 2).

Sampling of catches for stomach samples was carried out as other requirements of the program and circumstances permitted. Immediately after completion of the morphometric work aboard the ship the stomachs were removed by opening the abdominal cavity and by severing them from the intestine and the esophagus. Each stomach was pierced in several places to allow

TABLE 1.—Distribution of skipjack and yellowfin tuna stomachs collected during 1968 from the eastern tropical Atlantic Ocean, identified by month, cruise, and method of capture.

February UN6801[1]		March UN6801		April UN6801		September UN6802[2]		October UN6802		November UN6802		Total		
With food	Empty	With food	Empty	With food	Empty	With food	Empty	With food	Empty	With food	Empty	With food	Empty	Method of capture
						Skipjack tuna								
		20	28	292	36	70	4	104	69	25	5	511	142	Live bait
41	8	3	3					3				47	11	Trolling
						Yellowfin tuna								
				67		24	4	18	1			109	5	Live bait
4		9	1	3						1		17	1	Trolling

[1] UN6801 = RV *Undaunted* 6831 cruise.
[2] UN6802 = RV *Undaunted* 6802 cruise.

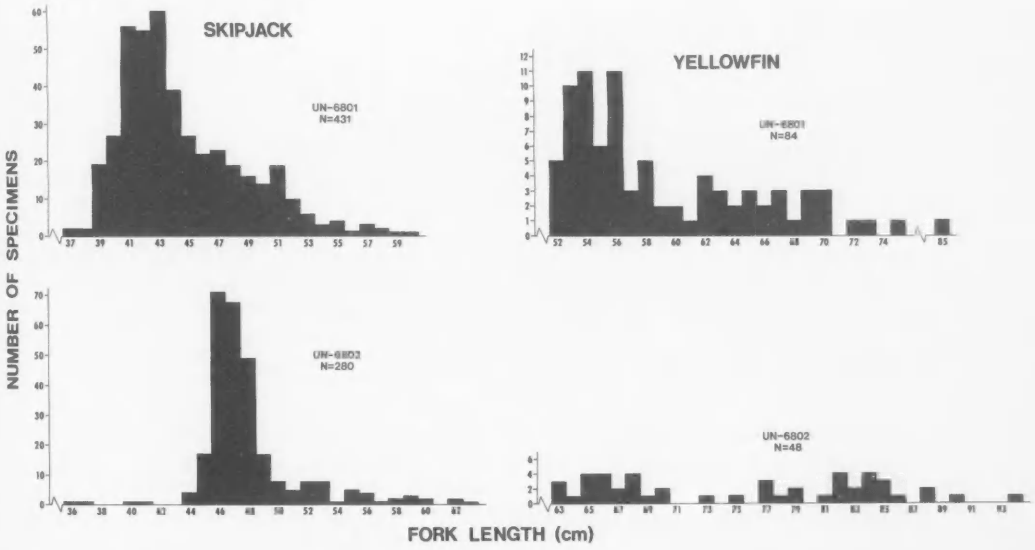

FIGURE 2.—Length-frequency distribution of skipjack tuna and yellowfin tunas from which stomachs were collected.

penetration of Formalin[3] and placed in a labeled polyethelene bag containing 10% Formalin.

In the laboratory the stomachs were first classified into those containing food and those that were empty. The stomach contents were then identified to the lowest possible taxonomic units which were subsequently sorted, counted, and their displacement volumes measured. Length measurements were taken of many forage organisms, particularly fishes. Bait fishes were found in some of the stomachs, but they were not considered as part of the regular diet of skipjack and yellowfin tunas; therefore, stomachs which contained only bait were considered empty. Stomachs that contained parasitic trematodes were also considered empty.

This study was no exception in regard to difficulties encountered in the identification of forage organisms (Dragovich, 1969). In numerous instances the identification of ingested fishes, particularly juvenile tunas, was made from vertebrae using methods employed by Potthoff and Richards (1970). Cephalopod identification was particularly difficult since many diagnostic external characters usually are the first destroyed during digestion.

The following methods of analysis were used: 1) the volumetric method—the individual volume of each taxon and the total aggregate volume of broad taxonomic groups, 2) frequency of occurrence method—the frequency of occurrence of a food item and of broad taxonomic groups, and 3) numerical method—number of individuals in the same taxonomic group.

Spearman's rank correlation test, χ^2 test of homogeneity, and paired t-test of difference between the means were used. A method consisting of ranking of food organisms according to their geographic distribution, relative abundance, and biomass was also employed.

COMPOSITION OF FOOD

Fishes, crustaceans, and cephalopods were the three principal food categories found in stomachs of both skipjack and yellowfin tunas (Figure 3). Food items that do not fall into these three categories consisted of mollusks other than cephalopods, salps, polychaetes, and siphonophores. Other mollusks and salps were found in both species of tunas; polychaetes and siphonophores were present only in stomachs of skipjack tunas. A checklist of all food items, number of organisms, frequency of occurrence, displacement volumes, and length measurements of some organisms are presented according to the cruises in Appendix Tables 1 to 4. Fishes were represented in the diet of skipjack and yellowfin tunas by 90 different taxa, crustaceans by 45, and mollusks by 24.

The percentage composition of five food categories in terms of number, volume, and frequency of occurrence is shown in Figure 3. Fish was the dominant food item by volume for both species of tunas, except for yellowfin tuna captured during UN6802, when cephalopods were dominant. Fish occurred most frequently in the diet of both species of tunas sampled during UN6801; however, crustaceans occurred most often in the collections from UN6802. In the diet of yellowfin tuna, fishes were numerically the most important food items during both cruises; in the diet of skipjack tuna, fishes were the most important by numbers during UN6801, but crustaceans were most numerous during UN6802.

The group of forage organisms classed as other mollusks consisted primarily of pteropods and heteropods. Salps, polychaetes, and siphonophores were the principal components of the group of forage organisms classed as miscellaneous—this group was not prominent by volume, frequency of occurrence, or by numbers.

FISHES

Fishes utilized as food consisted mainly of postlarval and juvenile forms of pelagic and reef fishes. Some adult fishes, primarily *Vinciguerria nimbaria*, were also present in the diet of both species of tuna. Although fishes were represented by a larger number of families, only a few families were important in terms of volume, frequency of occurrence, and numbers.

[3] Use of trade names does not imply endorsement by the National Marine Fisheries Service.

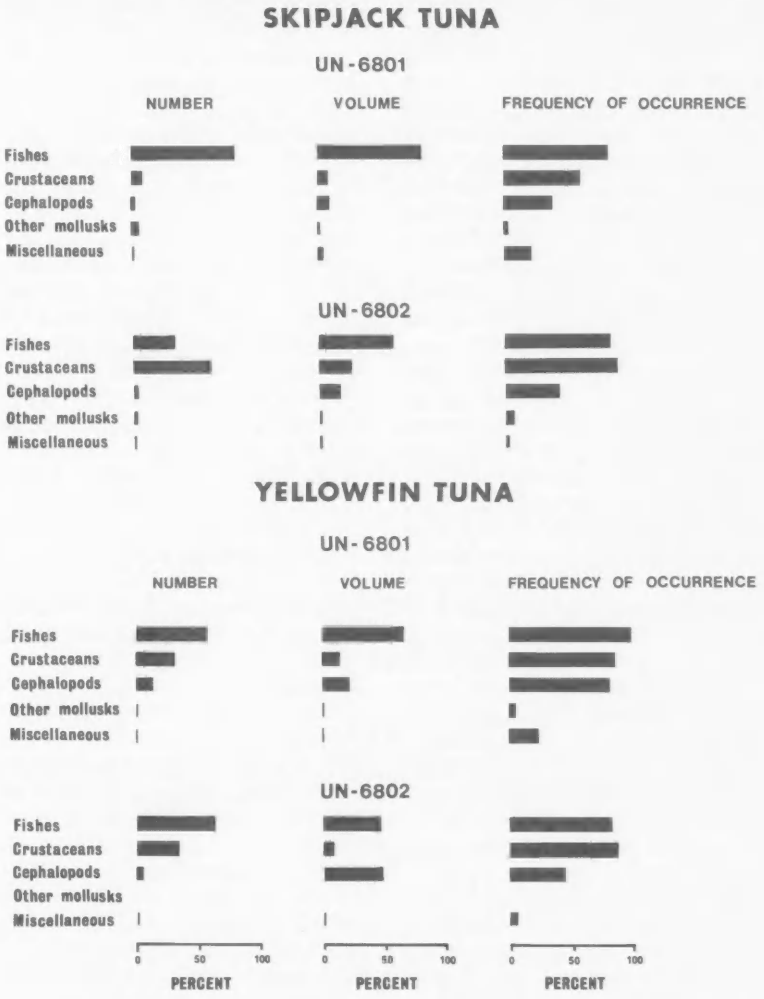

FIGURE 3.—Percentage of total food (by five categories) in stomachs of skipjack and yellowfin tunas captured during cruises UN6801 and UN6802 off the west coast of Africa. Food items are represented in terms of numbers, volumes, and frequency of occurrence.

For UN6801, fish families Acanthuridae, Carangidae, Dactylopteridae, Gempylidae, Gonostomatidae, Lutjanidae, Mullidae, Priacanthidae, Scombridae, and Serranidae ranked high in terms of volume and frequency of occurrence for both species of tunas. Owing to the large numbers of *V. nimbaria* in the diet of both species of tunas, the family Gonostomatidae was the most important forage item for both species in terms of volume. In the diet of skipjack tuna,

important contributors by volume were Gonostomatidae, 44.7%; Engraulidae, 8.9%; Mullidae, 7.9%; Gempylidae, 2.7%; Serranidae, 2.5%; Lutjanidae, 2.0%; Scombridae, 1.6%; Carangidae, 1.6%; and Priacanthidae, 1.5%. Important contributors by volume to the diet of yellowfin tuna were Gonostomatidae, 22.1%; Mullidae, 14.8%; Tetragonuridae, 6.3%; Carangidae, 3.8%; Paralepididae, 1.5%; Priacanthidae, 1.2%; and Scombridae, 1.0%. The remaining fish families contributed less than 1% per family for both species of tunas. The high volumetric contribution by the family Tetragonuridae was due to the large size of only four *Tetragonurus cuvieri*, which were found in a single stomach of a yellowfin tuna.

During UN6802 most important fish families by volume and by frequency of occurrence were Carangidae, Gempylidae, Paralepididae, Scombridae, and Trichiuridae. Serranidae and Scorpaenidae were prominent in the diet of skipjack tuna, but entirely absent in the diet of yellowfin tuna. Important contributors by volume in the diet of skipjack tuna were Paralepididae, 28.4%; Percoidei, 8.6%; Carangidae, 3.1%; Serranidae, 1.5%; Trichiuridae, 1.4%; Gempylidae, 1.3%; and Scombridae, 1.2%. In the diet of yellowfin tuna important contributors by volume were Exocoetidae, 9.6%; Alepisauridae, 5.6%; Carangidae, 2.7%; Trachypteridae, 2.6%; Scombridae, 2.5%; and Percoidei, 1.4%. The remaining fish families and suborders in the diet of both species of tunas contributed less than 1% per taxon in terms of volume. The relatively high contribution by the families Exocoetidae and Alepisauridae was due to the large volumes of only three forage fish (Appendix Table 4). From our data we see that some of the prominent forage fish families for both species of tunas were common to both cruises and that others were important during only one cruise (Appendix Tables 1-4).

CRUSTACEANS

As shown in previous publications (Dragovich, 1969, 1970), crustaceans, because of their high numbers and high frequency of occurrence, were important components of tuna food. Crustaceans found in tuna stomachs during both cruises were similar. The majority were larval stomatopods, hyperiid amphipods, and different types of megalopae or their equivalents. The highest number (32) of taxa was noted in the diet of skipjack tuna during UN6801, while in the diet of yellowfin tuna for the same cruise, 20 different taxa were identified—16 of these were common in the diet of both species of tunas. During UN6802, 22 different taxa were identified in the diet of skipjack tuna and 10 in the diet of yellowfin tuna—7 were common to both species of tuna. Stomatopods were not identified further than order. *Phronima sedentaria*, *Phrosina semilunata*, and *Brachyscellus* spp. were the most common amphipods in both tunas for both cruises. Megalopal stages probably consisted of many species, but due to the lack of taxonomic literature, they were not identified further than class or family.

A variety of anomurans and caridean shrimp were consumed by both species of tunas. *Dardanus pectinatus* (Glaucothoë) was the most important anomuran for both tunas during both cruises. Carideans were more prominent during UN6801 than during UN6802.

Euphausia hanseni was eaten by both tunas during UN6801. During UN6802, *E. hanseni* occurred in high numbers in the diet of skipjack tuna but was entirely absent in the food of yellowfin tuna. Since *E. hanseni* are of minute size, they were probably accidentally ingested or the skipjack tuna were filter feeding. The same explanation may be applied to other organisms of similar size found in the stomachs of both species of tunas, for example, copepods and isopods. Another explanation is that some of the euphausiids, copepods, or isopods could be the remains of stomach contents of other fishes ingested by tunas.

Phyllosoma occurred in low numbers in the diet of both species during both cruises. The identified forms were *Panulirus rissoni*, *Scyllarus arctus*, *Scyllarus* sp., and *Scyllaridea* sp.

MOLLUSKS

Cephalopods formed the bulk of the molluscan food of both species of tunas during both cruises.

Teuthoidea (squid) were the most important by volume and by frequency of occurrence in the diet of both species. Most of the squid belong to the family Ommastrephidae. Among identified omasterphids, *Ornithoteuthis antillarum* was most frequently encountered. This species was especially numerous in the food of skipjack tuna during UN6802. Octopoda were less numerous and occurred with less frequency than Teuthoidea. The displacement volume of some of the Octopoda (*Argonauta argo* and *A.* sp.) was very large. Five specimens of *A. argo* consumed by yellowfin tuna during UN6802 displaced 165.5 ml—more than all other mollusks combined for that cruise or all the fishes for that cruise (Appendix Table 4).

Among other mollusks, pteropods and heteropods were found in the stomachs of skipjack tuna during both cruises. They were absent in the food of yellowfin tuna during UN6802 and occurred only in two stomachs during UN6801. A heteropod, *Cavolinia longirostris*, occurred in high numbers in the diet of skipjack tuna during UN6801. In terms of volume, both of these mollusks were of minor importance.

JUVENILE TUNAS AS FOOD OF SKIPJACK AND YELLOWFIN TUNAS

Knowledge on the distribution and abundance of juvenile tunas and tunalike fishes is very limited because existing collection methods for juveniles are inadequate. This information is very important, however, as an aid in identifying spawning seasons and areas of tunas. One of the major sources of juvenile tunas is from stomachs of adult tunas. Juvenile tunas and tunalike fishes were present in the diet of both species of tunas sampled on both cruises. As many as 20 juvenile tunas were found in a single tuna stomach. The most frequently encountered and the most numerous juvenile tunas were *Auxis* spp. and little tunny (*Euthynnus alletteratus*) (Table 2). Specimens of *Auxis* spp. were found in both species of tunas during both cruises. Specimens of *E. alletteratus* were present in the diet of both species of tunas, but only during UN6801. All the remaining species of juvenile tunas occurred infrequently in small numbers. *Katsuwonus pelamis* and *Thunnus*

TABLE 2.—Occurrence of juvenile scombrids in the stomachs of skipjack and yellowfin tunas during cruises UN6801 and UN6802.

	Total number	Standard length (mm)		Number of juveniles in a single stomach	Frequency of occurrence		Displacement volumes	
		Range	Mean		Number	Percent	ml	Percent
				Skipjack tuna UN6801				
Unidentified Scombridae	4	--	--	1, 2	3	0.8	0.5	<0.1
Auxis spp.	53	12-37	29	1, 2, 3, 4, 9	29	8.1	9.5	0.3
Euthynnus alletteratus	120	10-68	29	1, 2, 3, 4, 5, 10	66	18.5	28.1	1.0
Katsuwonus pelamis	2	20-32	26	1	2	0.6	0.3	0.3
Thunnus spp.	2	34-47	41	1	2	0.6	1.4	<0.1
				Skipjack tuna UN6802				
Auxis spp.	33	15-63	31	1, 6, 16	10	5.0	8.6	0.9
Sarda sarda	4	25-43	34	1	4	2.0	2.3	0.2
Scomber japonicus	1	--	40	1	1	0.5	1.3	0.1
				Yellowfin tuna UN6801				
Auxis spp.	7	12-50	22	1, 2	5	6.0	1.4	<0.1
Euthynnus alletteratus	58	11-70	33	1, 2, 3, 4, 5, 6, 8	21	25.3	16.0	0.7
Katsuwonus pelamis	1	38	38	1	1	1.2	0.2	<0.1
Thunnus spp.	3	29-40	36	1	3	3.6	0.8	<0.1
				Yellowfin tuna UN6802				
Unidentified Scombridae	15	--	--	1, 3, 8	6	14.0	0.8	0.2
Auxis spp.	53	15-34	22	1, 2, 4, 7, 20	11	25.6	7.4	2.1
Sarda sarda	4	15-21	18	1, 3	2	4.7	0.5	0.1
Scomber japonicus	1	--	28	1	1	2.3	0.1	<0.1

spp. were found in the stomachs of both species of tunas, but only during UN6801. *Sarda sarda* and *Scomber japonicus* were also found in both skipjack and yellowfin tunas, but only during UN6802.

The presence of juvenile tunas in the diet of skipjack and yellowfin tunas in various parts of the Atlantic Ocean has been reported by Dragovich (1969, 1970). Presence of *Auxis* spp. and *Scomber* sp. in the diet of yellowfin tuna from east African waters was noted by Williams (1966). Suarez Caabro and Duarte Bello (1961) noted juvenile blackfin tuna (*Thunnus atlanticus*) (5-150 mm fork length) and skipjack tuna (35-145 mm fork length) in the stomachs of skipjack tuna from the Caribbean Sea. Presence of juvenile tunas in the diet of adult tunas has been frequently observed in food studies in the Pacific Ocean (Reintjes and King, 1953; King and Ikehara, 1956; Alverson, 1963; Nakamura, 1965).

COMPARISON OF FOOD OF SKIPJACK AND YELLOWFIN TUNAS

As in a previous study by Dragovich (1970), our data show a marked taxonomic similarity of items in the diet of skipjack and yellowfin tunas for the investigation area as a whole (Appendix Tables 1-4). We also compared the taxonomic composition of forage organisms at the two locations where skipjack and yellowfin tunas were caught together in a mixed school. For those locations we performed χ^2 tests of homogeneity on the ratio of fish to total volume of food. The first test indicated that the percentage of fish consumed differs between the two locations ($\chi^2 = 6.74$; 1 *df*; $P < 0.1$) possibly reflecting differences in forage-at-large composition, times of day, size frequency of tuna, etc. Within-area difference in percent fish between yellowfin and skipjack tunas was significant in only one area ($\chi^2 = 62.51$; 1 *df*; $P < 0.01$).

TABLE 3.—The distribution of displacement volumes of individual forage organisms collected during the cruises of UN6801 and UN6802.

Food item	Total range of displacement volumes (ml)	Displacement volumes in 90% of observations
	Skipjack tuna	
Fish	0.1- 8.2	0.1-0.3
Crustaceans	0.1- 1.2	0.1
Cephalopods	0.1- 6.5	0.1-1.6
Other mollusks	0.1- 0.4	0.1
Salps	0.1- 3.5	0.1-0.7
	Yellowfin tuna	
Fish	0.1-55.0	0.1-0.5
Crustaceans	0.1- 1.0	0.1
Cephalopods	0.1-50.5	0.1-0.7
Salps	0.1	0.1

VARIATION IN FOOD AS RELATED TO SIZE OF TUNAS AND VOLUME OF STOMACH CONTENTS

The foods of skipjack and yellowfin tunas in the present study consisted principally of relatively small organisms, based on their displacement volumes (Table 3). The consumption of organisms of comparable size in similar proportions by skipjack and yellowfin tunas has also been observed by other investigators (Reintjes and King, 1953; King and Ikehara, 1956; Nakamura, 1965; Williams, 1966; Dragovich, 1970).

To observe the differences in consumption of food by volume and frequency of occurrence of the three major food categories as related to size of tunas, skipjack and yellowfin tunas were separated into 20 mm and 30 mm length intervals respectively (Figure 4). Spearman's rank correlation analysis (Steel and Torrie, 1960:409) was used to see if the volumes and frequency of occurrence of the two dominant forage food items (fishes and crustaceans) in the diet of skipjack and yellowfin tunas were correlated with the size of tunas. Significant correlations in the length-food data were noted between the size of skipjack tuna and percentage volume of fish forage (r_s 0.576, 11 *df*, $P < 0.05$) and percentage of occurrence of forage fish (r_s 0.565, 11 *df*, $P < 0.05$), suggesting that as the size of tuna increased, the percentage consumption of fish by volume and by frequency of occurrence increased.

It is generally recognized that the amount and quality of food found in the stomach of tunas

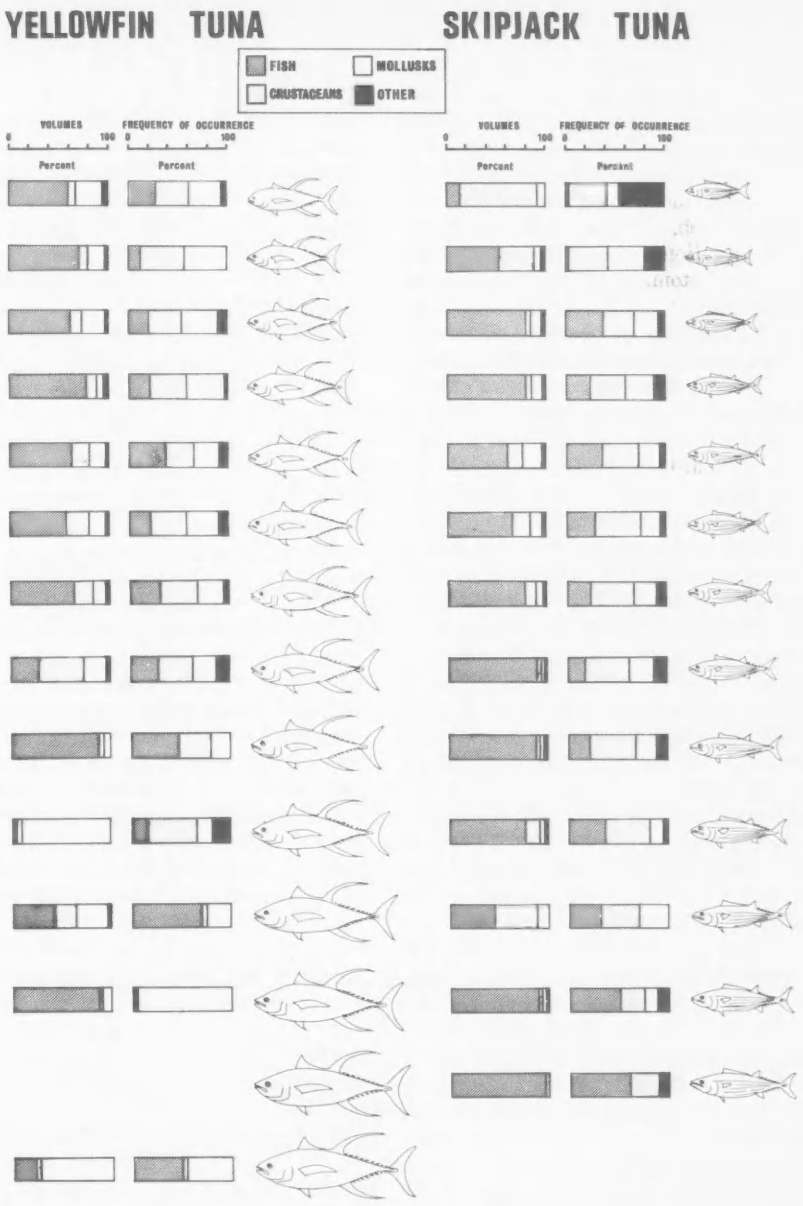

FIGURE 4.—The distribution of volumes and frequencies of occurrence of the major food categories (fish, crustaceans, mollusks, and miscellaneous) at various sizes of skipjack and yellowfin tunas off the west coast of Africa, The sizes of skipjack range from 370 mm to 610 mm (intervals 20 mm); the sizes of yellowfin tuna range from 520 mm to 910 mm (intervals 30 mm).

are important in studies concerned with energy that is converted into caloric equivalents of energy utilized for growth. We have the information only on the volumes of the stomach contents. This information may be of interest to the investigators concerned with energy budgets of tunas and with studies on transfers of energy within the food web. In our study, in the majority of observations, the displacement volumes of the total stomach contents of skipjack and yellowfin tunas varied from 0.1 to 20.0 ml and from 0.1 to 60.0 ml, respectively (Table 4). Information on the volumes of stomach contents of tunas in the Atlantic Ocean is found only in a limited number of investigations, as cited in the review of studies of tuna food in the Atlantic Ocean by Dragovich (1969). Dragovich (1970) noted volumes of stomachs of less than 20 ml in 75% of skipjack tuna sampled and in 85% of yellowfin tuna. Volumes of stomach contents of yellowfin tuna caught by longline off the coast of east Africa (Williams, 1966) were generally higher than those in our study. The majority of the volumes measured by Williams fell within a range of 3.0 to 499.9 cc. Higher volumes of stomach contents observed by Williams may be partially explained by the fact that tunas caught on longline are usually larger than fishes caught by surface methods.

To determine the relation between the volume of stomach contents and body weight of skipjack and yellowfin tunas, we have assumed that 1.0 ml of stomach contents is equivalent to 1.0 g. Comparisons on this basis were made between the estimated weight of the stomach contents and the body weights of tunas. Our calculations have shown that the total volume of stomach contents for both species of tunas in almost all observations was well below 1.0% of the body weight. This observation is in agreement with the findings by Dragovich (1970). The results of these calculations suggest that there was little difference in the total amount of food found in the stomachs of both species of tunas as related to the body weight. Possible explanations for such low volumes of stomach contents may be rapid digestion of food, long periods between the feedings, scarcity of food, and the fact that most of the forage organisms are very small macrozooplankton.

SEASONAL CHANGES IN TAXONOMIC COMPOSITION OF FORAGE ORGANISMS

Cruise UN6801 took place in the Gulf of Guinea during what is sometimes called the "warm" season (February, March, and April) and UN6802 during the "cool" season (September, October, and November). Berrit (1961) in his study on seasonal variations of oceanographic conditions introduced these terms. Results on studies by Sund and Richards (1967)

TABLE 4.—Distribution of the volumes of total stomach contents in 711 skipjack tuna and 132 yellowfin tuna stomachs. The data were collected during cruises UN6801 and UN6802.

Volume of stomach contents (ml)	Skipjack tuna			Yellowfin tuna		
	Number of stomachs	Percentage	Accumulated percentage	Number of stomachs	Percentage	Accumulated percentage
Empty	153	21.5	21.5	6	4.5	4.5
0.1-0.5	127	17.9	39.4	8	6.1	10.6
0.6-1.0	70	9.8	49.2	7	5.3	15.9
1.1-1.9	69	9.7	58.9	9	6.8	22.7
2.0-2.9	46	6.5	65.4	10	7.6	30.3
3.0-3.9	37	5.2	70.6	5	3.8	34.1
4.0-4.9	32	4.5	75.1	10	7.6	41.7
5.0-10.0	80	11.2	86.3	15	11.4	53.1
10.1-20.0	63	8.9	95.2	15	11.4	64.5
20.1-60.0	24	3.4	98.6	34	25.7	90.2
60.1-100.0	6	0.8	99.4	12	9.1	99.3
100.1-200.0	4	0.6	100.0	1	0.7	100.0

on the differences in the occurrence of forage organisms of skipjack and yellowfin tunas in the Gulf of Guinea between these two seasons are compared with ours.

In our study, the fish families present in the diet of both species of tunas only during the "warm" period were Mullidae, Dactylopteridae, Gonostomatidae, and Engraulidae. In the study of Sund and Richards (1967), Dactylopteridae were also present during the "warm" season only. A number of crustacean taxa were present in our study only during the "warm" season and absent during the "cool" season. Grapsidae (megalopal stages), *Petrochirus* sp. and *Streetia challengeri*, were found only during the "warm" period and absent during the "cool" period. Other prominent crustaceans observed by us in stomachs of both species of tunas only during the "cool" period were *Vibilia armata*, *Scyllarides* sp., *Scyllarus* sp., and *S. arctus*. Some of the crustaceans (*Phronima sedentaria*, *Phrosina semilunata*, *Euphausia* sp.) occurred only in one season in the observations of Sund and Richards (1967), whereas we observed them in both seasons. More extensive collections are needed before any final evaluation is made in regard to the significance of the occurrence of these organisms during different seasons.

EVALUATION OF FOOD ORGANISMS

In selecting the most important food organisms in a given area, many variables have to be considered. Reintjes and King (1953) stated that food items that rank high in number, high in volume, and high in frequency of occurrence are important foods—at the time and in the area sampled. Using these criteria plus the geographic distribution in evaluation of food organisms of both species of tunas, we have calculated dispersal and abundance indices and mean displacement volumes for each food taxon and ranked them accordingly.

The entire investigation area was divided into 27 one-degree squares. If a taxon was present in one square it was assigned a value of one. Using the data from both cruises and for both species of tunas combined, the number of occurrences of each taxon in 27 squares was divided by the number of squares—the quotient was called the dispersal index. An abundance index was calculated by dividing the total number of individuals in each taxon by the total number of all organisms. An approximation of biomass of each food item was represented by the mean displacement volume. The mean displacement volume of food items represented in Figure 5 varied from 0.1 to 0.7 ml.

Since a large number of taxa are represented, we have selected the 32 taxa with the highest dispersal and abundance indices and presented them in a descending order of magnitude (Figure 5). *Vinciguerria nimbaria* and *Anchoviella guineensis*, although with low dispersal indices, were included in the diagram because of their high abundance indices. From Figure 5 it is obvious that Stomatopoda, *Phrosina semilunata*, Teuthoidea, Carangidae, Serranidae, and megalopal stages were the most important identifiable food items throughout the investigation area while *V. nimbaria*, *Euphausia hanseni*, and *A. guineensis* were of great local importance.

In the evaluation of forage organisms by the present method we consider the geographic dispersal of food organisms to be the most important criterion for the survival of skipjack and yellowfin tunas, particularly since these tunas are migratory and widely distributed. In our study the tuna forage organisms were both widely distributed and abundant in the area of sampling as indicated in Figure 5. High abundance indices were usually associated with high dispersal indices. Thus these food organisms may be considered to be important in the food chain of skipjack and yellowfin tunas for the given time and area.

The disadvantage of the method is that the estimated geographic distribution of forage taxa as calculated from stomach contents may not represent the true distribution. The only other information nearest to the natural distribution of certain forage organisms found in our study was obtained from zooplankton double oblique tows which were made at about the same time of the capture of tunas from which stomach samples were taken. The preliminary analysis of the composition of zooplankton from these

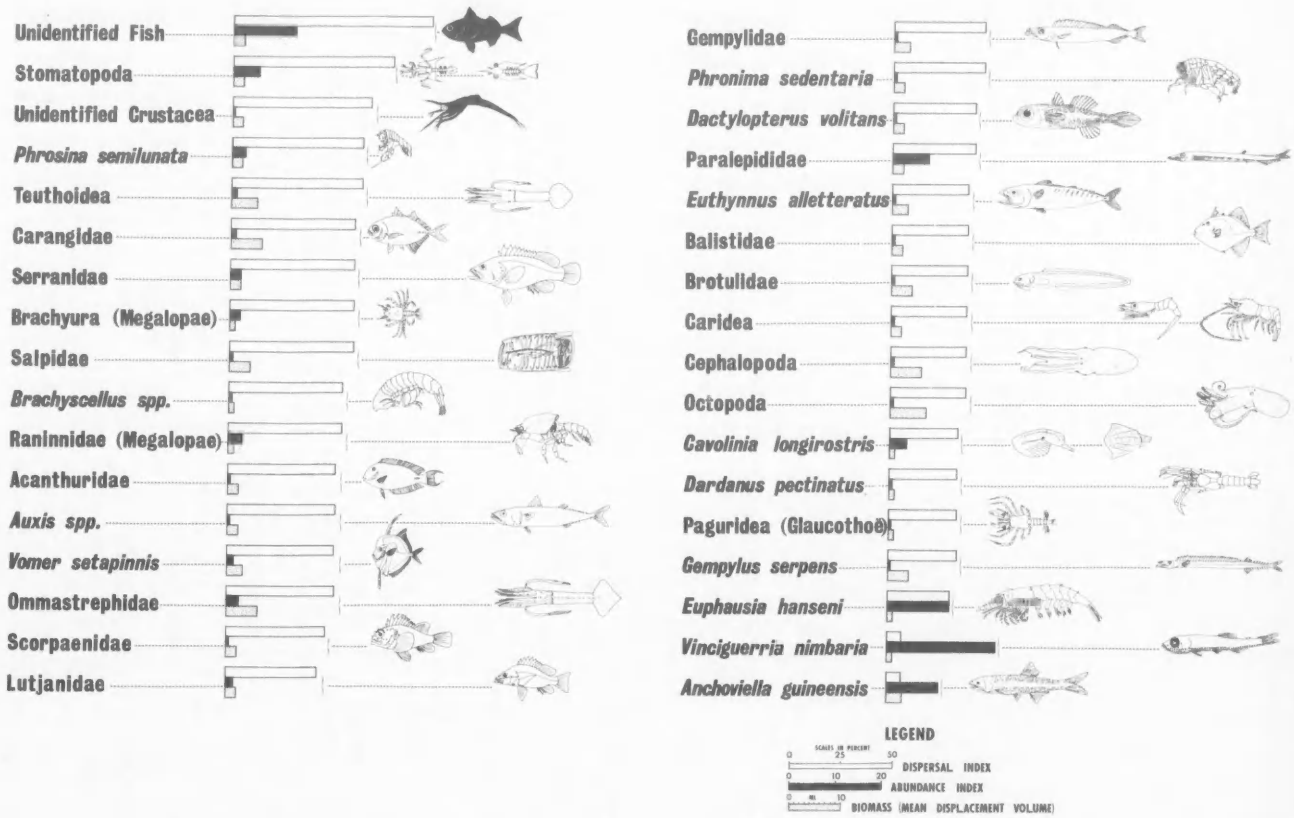

FIGURE 5.—The dispersal and abundance indices and biomass of forage organisms of skipjack and yellowfin tunas off the west coast of Africa. Dispersal and abundance indices expressed in percent. The biomass expressed in milliliters.

plankton samples showed that the major constituents were copepods and arrowworms. Arrowworms were entirely absent in the diet of both species of tunas. Although copepods were present in the stomachs of a few skipjack tunas, they may have been remains of the stomach contents of the ingested fishes. Among the minor constituents of zooplankton, 60 species and 10 genera of amphipods and 20 species and 3 genera of euphausiids were present in the plankton tows. Although all of the amphipods and euphausiids found in the tuna stomachs were also present in the plankton tows, their number represented only a small fraction of the number of taxa found in the plankton tows, thus suggesting selectivity in feeding of skipjack and yellowfin tunas. Our findings support those of Blackburn (1965), who stated that no species of tuna consumes all the species of net-caught micronekton or zooplankton.

COMPARISONS WITH RESULTS OF OTHER INVESTIGATORS

Investigations concerned with the food of skipjack and yellowfin tunas off the west coast of Africa are numerous (Postel, 1954, 1955a, 1955b; Marchal, 1959; de Jager, de V. Nepgen, and van Wyk, 1963; Penrith, 1963; Sund and Richards, 1967; de V. Nepgen, 1970; and Dragovich, 1970). Reliable qualitative comparisons of tuna forage between different studies are difficult because identification of organisms is usually incomplete. Quantitative comparisons between various studies of tuna forage usually consist of comparisons between the major food categories (fishes, crustaceans, and cephalopods). The nearest areas of the Atlantic Ocean to our investigation area for which valid comparisons can be made were investigated by Marchal (1959), Sund and Richards (1967), and Dragovich (1970).

The diet of yellowfin and skipjack tunas in the Gulf of Guinea was studied by Marchal (1959) and Sund and Richards (1967), respectively. From a long list of forage organisms presented by Marchal only several fishes (*Vomer setapinnis, Euthynnus alletteratus, Sternoptyx diaphana, Hyppocampus* sp., *Ophidion barbatum,* Brotulidae, Chiasmodontidae), a few crustaceans (Stomatopoda, *Heterocarpus ensifer,* Glaucothoë, megalopae (Brachyura)), and salps were common to both studies. All fish families in the diet of yellowfin tuna and skipjack tuna observed by Sund and Richards (1967) were also observed by us. The differences in the composition of tuna food between our study and that of Sund and Richards were on generic and specific levels except for cephalopods, where our findings differed entirely.

A striking similarity in the food of skipjack and yellowfin tunas was observed between our study and that of Dragovich (1970). Skipjack and yellowfin tunas in the study by Dragovich were captured off the coast of West Africa from Sierra Leone to Angola. All forage-fish families (21) in the diet of skipjack tuna noted by Dragovich were also observed by us. The most prominent fish families (Carangidae, Scombridae, Gempylidae) in terms of volume of frequency of occurrence observed by Dragovich were equally important in our study. We found the same groups of crustaceans as Dragovich. In the cephalopod diet ommastrephids were the principal food in both studies.

Postel (1955a) examined contents of stomachs of yellowfin tuna caught off the coast of Senegal. Of 30 species and 7 genera of fish and 12 cephalopod taxa listed by Postel, only *Euthynnus alletteratus, Katsuwonus pelamis, Sphyraena* sp., *Cranchia scabra,* and *Argonauta* sp. were observed by us. None of the identified species and genera of crustaceans by Postel was observed by us. The pronounced taxonomic differences of forage between our study and that of Postel may be partially explained by the different oceanographic regime off the coast of Senegal.

Postel (1955b), in his report on *Katsuwonus pelamis* off Cape Verde Islands, identified *Sardinella aurita, S.* sp., Myctophidae, *Hemiramphus* sp., *Hyporamphus* sp., *Gephyroberyx darwini, Scomber colias, Aphanopus* sp., and Mullidae in the diet of this tuna. Myctophidae and Mullidae were also observed by us in the diet of skipjack tuna. From cephalopods, only *Illex illecebrosus coindeti* was listed; this species was not identified in the diet of skipjack by us.

De Jager, de V. Nepgen, and van Wyk (1963), de V. Nepgen (1970), and Penrith (1963) reported that the food of yellowfin tuna caught off South Africa consisted mainly of fish. De Jager, de V. Nepgen, and van Wyk stated that lanternfish and anchovies occurred more frequently in the diet of yellowfin tuna than in the diet of other species of tunas; crab megalopae were by far the highest ranking crustaceans. Fish in de V. Nepgen's (1970) study consisted chiefly of garfish, lanternfish, and mackerel (*Scomber japonicus*). Most of the forage fishes reported by Penrith (1963) were surface fishes (*Scomberesox saurus, Coryphaena hippurus*, juvenile Bramidae). Among crustaceans Penrith (1963) found that yellowfin tuna fed chiefly on the deep-living prawn, *Funchalia woodwardii*. Megalopae also played an important role in the food of yellowfin tuna and were more important than amphipods. Mollusks consisted of unidentified cephalopods (squid), heteropods, and pteropods. In our study lanternfish and mackerel were unimportant as forage for yellowfin and skipjack tunas, and anchovies were not eaten by yellowfin tuna but occurred in great numbers in the diet of skipjack tuna; megalopae were among the highest ranking crustaceans. From a high number of forage fishes listed by Penrith (1963) only unidentified Carangidae, *Naucrates ductor*, unidentified Priacanthidae, *Priacanthus* sp., Acanthuridae, Scombridae, Balistidae, Blennidae, Bramidae, Coryphaenidae, *Coryphaena hippurus*, and Syngnathidae were also observed by us. Crustaceans common to Penrith's and our study were stomatopods, amphipods (*Phronima sedentaria, Phrosina semilunata*), and megalopae (Brachyura). Molluscan food for the most part was different between our study and that of Penrith (1963).

On the basis of the studies discussed in this section, it is evident that skipjack and yellowfin tunas consume a great variety of forage organisms. Fish, cephalopods, and crustaceans were the principal foods of both species of tunas in all investigations. The similarity in regard to the taxonomic composition of forage between different studies was greater when the investigations were made in the same general area. In each given area, only several types of food were important. Although occasionally bottom organisms were found in the diet of a skipjack and particularly yellowfin tunas, both of these species primarily feed on juvenile pelagic organisms.

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APPENDIX TABLE 1.—List of forage organisms found in stomachs from 356 skipjack tunas, collected off the west coast of Africa during UN6801. Number of organisms, frequency of occurrence, and percentage of total volume are given for each taxon. Size ranges and mean sizes are given only for certain forage fishes. Fishes are listed in decreasing order of frequency of occurrence by families; crustaceans, mollusks, and miscellaneous groups are listed by broad categories.

Taxon	Number of organisms	Frequency of occurrence		Volume		Size (mm)	
		Number	%	ml	%	Range	Mean
Fishes:							
Unidentifiable	1,912	229	64.3	179.5	6.5	7-57	19
Carangidae							
Vomer setapinnis	174	88	24.7	25.3	0.9	8-33	15
Decapterus spp.	6	5	1.4	1.5	<0.1	20-43	25
Unidentified Carangidae	85	54	15.2	14.8	0.5	8-46	20
Scombridae							
Euthynnus alletteratus	120	66	18.5	28.1	1.0	10-68	29
Auxis spp.	53	29	8.1	9.5	0.3	12-37	29
Katsuwonus pelamis	2	2	0.6	0.3	<0.1	20-32	26
Thunnus spp.	2	2	0.6	1.4	<0.1	34-47	41
Unidentified Scombridae	4	3	0.8	0.5	<0.1		
Gempylidae							
Gempylus serpens	48	28	7.9	34.3	1.2	18-216	70
Nealotus tripes	13	11	3.1	10.2	0.4	20-85	51
Promethichthys prometheus	8	7	2.0	3.0	0.1	24-65	45
Nesiarchus nasutus	1	1	0.3	0.1	<0.1		
Unidentified Gempylidae	89	54	15.2	26.4	0.9	18-83	57
Mullidae							
Pseudupeneus prayensis	278	80	22.5	196.8	7.1	32-49	42
Unidentified Mullidae	45	18	5.1	22.1	0.8	40-48	44
Priacanthidae							
Priacanthus spp.	84	50	14.0	23.6	0.9	9-31	21
Priacanthus arenatus	24	14	3.9	15.8	0.6	22-33	30
Lutjanidae							
Unidentified Lutjanidae	392	64	18.0	55.3	2.0	10-36	18
Serranidae							
Unidentified Serranidae	395	62	17.4	69.8	2.5	11-28	20
Acanthuridae							
Acanthurus monroviae	21	11	3.1	10.1	0.4	13-30	24
Unidentified Acanthuridae	65	40	11.2	13.8	0.5	6-29	18
Dactylopteridae							
Dactylopterus volitans	62	49	13.8	16.5	0.6	11-34	19
Gonostomatidae							
Vinciguerria nimbaria	5,237	38	10.7	1233.9	44.6	27-48	35
Unidentified Gonostomatidae	26	6	1.7	1.9	0.1	32-41	37
Engraulidae							
Anchoviella guineensis	3,098	25	7.0	247.0	8.9	21-34	27
Synodontidae							
Saurida brasiliensis	108	8	2.2	11.0	0.4	14-32	25
Unidentified Synodontidae	106	17	4.8	11.9	0.4	23-39	31
Bothidae							
Unidentified Bothidae	43	23	6.5	5.0	0.2	16-30	23
Balistidae							
Unidentified Balistidae	22	19	5.3	5.1	0.2	4-20	15
Tetraodontidae							
Unidentified Tetraodontidae	22	18	5.1	3.5	0.1	10-18	13
Paralepididae							
Unidentified Paralepididae	64	13	3.7	5.9	0.2	34-71	46
Anguilloidei							
Unidentified Anguilloidei	20	13	3.7	2.7	0.1		
Holocentridae							
Unidentified Holocentridae	12	12	3.4	3.2	0.1	10-36	24
Scorpaenidae							
Unidentified Scorpaenidae	13	12	3.4	1.7	0.1	4-20	13
Blennidae							
Ophioblennius webbi	10	9	2.5	3.3	0.1	29-42	34
Aulopidae							
Aulopus spp.	5	4	1.1	1.4	<0.1	26-45	33

APPENDIX TABLE 1.—Continued.

Taxon	Number of organisms	Frequency of occurrence		Volume		Size (mm)	
		Number	%	ml	%	Range	Mean
Bramidae							
Pterycombus brama	2	2	0.6	1.4	<0.1	28-36	32
Taractichthys longipinnis	1	1	0.3	0.3	<0.1		
Unidentified Bramidae	1	1	0.3	0.2	<0.1		
Chiasmodontidae							
Dysalotus spp.	4	4	1.1	2.0	<0.1	18-39	32
Ophichthidae							
Unidentified Ophichthidae	2	2	0.6	0.2	<0.1		
Sternoptychidae							
Sternoptyx diaphana	2	2	0.6	1.4	<0.1	20-26	23
Myctophidae							
Unidentified Myctophidae	10	2	0.6	0.3	<0.1	7-9	8
Chaunacidae							
Chaunax pictus	2	2	0.6	0.2	<0.1	8-9	9
Brotulidae							
Unidentified Brotulidae	2	2	0.6	0.7	<0.1	28-44	36
Exocoetidae							
Unidentified Exocoetidae	2	2	0.6	2.7	<0.1		
Trachipteridae							
Trachipterus trachypterus	2	2	0.6	0.5	<0.1	47-51	49
Triglidae							
Chelidonichthys gabonensis	2	2	0.6	0.6	<0.1	20-22	21
Sphyraenidae							
Sphyraena spp.	3	2	0.6	0.5	<0.1	28-31	29
Uranoscopidae							
Uranoscopus spp.	2	2	0.6	0.5	<0.1	17	17
Trichiuridae							
Unidentified Trichiuridae	4	2	0.6	0.8	<0.1	42-83	68
Istiophoridae							
Unidentified Istiophoridae	2	2	0.6	0.2	<0.1	13-17	15
Monacanthidae							
Unidentified Monacanthidae	2	2	0.6	3.6	0.1	15-51	33
Ostraciontidae							
Unidentified Ostraciontidae	2	2	0.6	0.3	<0.1	8-10	9
Congridae							
Unidentified Congridae	1	1	0.3	0.2	<0.1		
Antennariidae							
Unidentified Antennariidae	1	1	0.3	0.3	<0.1		
Aulostomidae							
Aulostomus maculatus	1	1	0.3	0.2	<0.1		
Stromatedoidei							
Unidentified Stromatedoidei	1	1	0.3	0.1	<0.1		
Ariommidae							
Ariomma spp.	1	1	0.3	1.3	<0.1		
Chaetodontidae							
Unidentified Chaetodontidae	1	1	0.3	0.2	<0.1		
Crustaceans:							
Unidentified Crustacea	--	52	14.6	17.0	0.6		
Stomatopoda							
Unidentified Stomatopoda	346	115	32.3	49.8	1.8		
Decapoda							
Brachyura (megalopae)	268	26	7.3	13.3	0.5		
Brachyura (zoea)	7	1	0.3	0.2	<0.1		
Raninidae (megalopae)	473	55	15.4	44.0	1.6		
Grapsidae (megalopae)	2	2	0.6	0.3	<0.1		
Anomoura							
Porcellanidae (megalopae)	9	2	0.6	0.3	<0.1		
Dardanus pectinatus (Glaucothoë)	20	11	3.1	1.9	<0.1		
Petrochirus sp. (Glaucothoë)	4	4	1.1	0.5	<0.1		
Unidentified Paguridea (Glaucothoë)	11	11	3.1	0.4	<0.1		
Macrura-Natantia							
Sergestes sp.	1	1	0.3	0.3	<0.1		
Lucifer sp.	1	1	0.3	0.3	<0.1		

APPENDIX TABLE 1.—Continued.

Taxon	Number of organisms	Frequency of occurrence		Volume		Size (mm)	
		Number	%	ml	%	Range	Mean
Caridea							
Brachycarpus biguinculatus (Retrocaris spinosa—larval stage)	33	23	6.5	2.8	<0.1		
Eretmocaris sp. (larvae of *Lysmata* sp.—Hyppolytidae)	1	1	0.3	0.1	<0.1		
Enoplometopus antilensis	1	1	0.3	0.5	<0.1		
Heterocarpus ensifer	7	6	1.7	1.0	<0.1		
Procletes stage (*Heterocarpus ensifer*)	4	3	0.8	0.4	<0.1		
Anisocaris sp. (larval Caridean genus)	1	1	0.3	0.2	<0.1		
Hippolytidae (larvae)	1	1	0.3	0.1	<0.1		
Unidentified Caridea	14	13	3.7	1.7	<0.1		
Macrura-Reptantia (all Phyllosoma stages)							
Unidentified Macrura-Reptantia	1	2	0.6	0.3	<0.1		
Panulirus rissoni	1	1	0.3	0.2	<0.1		
Amphipoda (Hyperidea)							
Phrosina semilunata	56	42	11.8	9.0	0.3		
Brachyscellus spp.	49	35	9.8	4.4	0.2		
Phronima sedentaria	52	41	11.5	7.9	0.3		
Oxycephalus clausii	10	10	2.8	1.1	<0.1		
Platyscellus ovoides	6	6	1.7	0.8	<0.1		
Anchylomera blossevillei	3	2	0.6	0.2	<0.1		
Vibilia cultripes	1	1	0.3	0.1	<0.1		
Streetsia challengeri	1	1	0.3	0.1	<0.1		
Platyscellus armatus var. *inermis*	1	1	0.3	0.1	<0.1		
Unidentified Hyperidea	9	4	1.1	1.8	<0.1		
Copepoda							
Unidentified Copepoda	6	3	0.8	0.3	<0.1		
Isopoda							
Cymathoidae	1	1	0.3	0.1	<0.1		
Euphausiacea							
Euphausia hanseni	5	5	1.4	0.5	<0.1		
Mollusks:							
Cephalopoda (adults and juveniles)							
Unidentified Cephalopoda	18	15	4.2	9.6	0.3		
Octopoda	27	13	3.7	10.0	0.4		
Argonauta argo	4	1	0.3	9.0	0.3		
Teuthoidea							
Unidentified Ommastrephidae	189	28	7.9	129.1	4.7		
Unidentified Teuthoidea	99	84	23.6	41.8	1.5		
Gastropoda							
Pteropoda							
Cavolinia longirostris	923	17	4.8	20.4	0.7		
Diacria trispinosa	1	1	0.3	0.1	<0.1		
Heteropoda							
Oxygyrus keraudreni	1	1	0.3	0.1	<0.1		
Atlanta peroni	2	2	0.6	0.2	<0.1		
Miscellaneous:							
Salpidae	85	49	13.8	63.0	2.3		
Polychaeta	1	1	0.3	0.2	<0.1		
Syphonophora	1	1	0.3	0.1	<0.1		
Unidentifiable		23	6.5	5.0	0.2		

APPENDIX TABLE 2.—List of forage organisms found in stomachs from 83 yellowfin tunas collected off the west coast of Africa during cruise UN6801. Number of organisms, frequency of occurrence, and percentage of total volume are given for each taxon. Size range and mean sizes are given only for certain forage fishes. Fishes are listed in decreasing order of frequency of occurrence by families; crustaceans, mollusks, and miscellaneous groups are listed by broad categories.

Taxon	Number of organisms	Frequency of occurrence		Volume		Size (mm)	
		Number	%	ml	%	Range	Mean
Fishes:							
Unidentifiable	748	69	83.1	230.0	10.4	11-43	27
Carangidae							
Vomer setapinnis	101	36	43.4	23.3	0.9	8-32	16
Decapterus spp.	1	1	1.2	0.8	<0.1		
Naucrates ductor	1	1	1.2	55.0	2.2		
Unidentified Carangidae	107	31	37.3	14.3	0.6	9-40	19
Mullidae							
Pseudopeneus prayensis	386	24	28.9	227.4	9.3	23-51	42
Unidentified Mullidae	315	20	24.1	136.2	5.5	39-51	44
Priacanthidae							
Priacanthus spp.	66	31	37.3	17.3	0.7	13-34	20
Priacanthus arenatus	15	10	12.0	9.1	0.4	18-32	27
Priacanthus cruenatus	1	1	1.2	0.7	<0.1		29
Acanthuridae							
Acanthurus monroviae	50	8	9.6	11.3	0.5	15-27	21
Unidentified Acanthuridae	44	26	31.3	7.7	0.3	11-30	20
Scombridae							
Euthynnus alleteratus	58	21	25.3	18.0	0.7	11-70	33
Auxis spp.	7	5	6.0	1.4	<0.1	12-50	22
Thunnus spp.	3	3	3.6	0.8	<0.1	29-40	36
Katsuwonus pelamis	1	1	1.2	0.2	<0.1		38
Gonostomatidae							
Vinciguerria nimbaria	1,163	23	27.7	518.8	21.1	32-50	40
Unidentified Gonostomatidae	78	7	8.4	24.5	1.0	17-44	29
Bothidae							
Unidentified Bothidae	86	29	34.9	11.2	0.5	15-50	24
Dactylopteridae							
Dactylopterus volitans	45	25	30.1	5.9	0.2	10-25	17
Balistidae							
Unidentified Balistidae	84	23	27.7	16.0	0.7	10-19	14
Gempylidae							
Gempylus serpens	9	6	7.2	2.8	<0.1	44-118	65
Nealotus tripes	2	2	2.4	1.1	<0.1	19-71	45
Nesiarchus nasutus	1	1	1.2	0.2	<0.1		
Promethichthys prometheus	1	1	1.2	0.2	<0.1		
Unidentified Gempylidae	14	12	14.5	3.5	<0.1		
Serranidae							
Unidentified Serranidae	43	18	21.7	7.1	0.3	16-26	21
Lutjanidae							
Unidentified Lutjanidae	29	17	20.5	5.1	0.2	14-38	22
Tetraodontidae							
Unidentified Tetraodontidae	18	16	19.3	3.8	0.2	9-36	16
Blenniidae							
Ophioblennius webbi	27	14	16.9	7.8	0.3	15-40	32
Paralepididae							
Unidentified Paralepididae	130	13	15.7	37.2	1.5	36-100	66
Holocentridae							
Myripristis jacobus	2	2	2.4	0.6	<0.1	22-26	24
Unidentified Holocentridae	20	11	13.3	5.8	0.2	11-32	23
Scorpaenidae							
Unidentified Scorpaenidae	13	13	15.7	3.2	<0.1	11-29	18
Anguilloidei							
Unidentified Anguilloidei	25	11	13.3	2.7	<0.1		
Sternoptychidae							
Sternoptyx diaphana	7	5	6.0	7.0	0.3	25-32	29
Unidentified Sternoptychidae	4	3	3.6	1.9	<0.1	20-27	24
Unidentified Stromateoidei	8	6	7.2	1.8	<0.1	18-34	26
Aulopidae							
Aulopus spp.	11	5	6.0	5.7	0.2	26-49	38

APPENDIX TABLE 2.—Continued.

Taxon	Number of organisms	Frequency of occurrence		Volume		Size (mm)	
		Number	%	ml	%	Range	Mean
Trachipteridae							
Trachipterus trachypterus	8	5	6.0	4.0	0.2	45-70	53
Syngnathidae							
Hippocampus spp.	2	1	1.2	0.1	<0.1	16-22	19
Hippocampus punctulatus	2	2	2.4	1.2	<0.1	50-52	51
Unidentified Syngnathidae	2	2	2.4	0.3	<0.1		
Ophichthidae							
Unidentified Ophichthidae	19	4	4.8	2.1	<0.1	80-108	96
Bramidae							
Pterycombus brama	1	1	1.2	0.4	<0.1		
Unidentified Bramidae	2	2	2.4	0.4	<0.1	14-19	17
Nettastomidae							
Unidentified Nettastomidae	7	2	2.4	1.0	<0.1		
Congridae							
Unidentified Congridae	7	2	2.4	2.1	<0.1	80-178	129
Synodontidae							
Saurida brasiliensis	7	1	1.2	1.2	<0.1	31-32	32
Unidentified Synodontidae	1	1	1.2	0.1	<0.1		
Myctophidae							
Unidentified Myctophidae	3	2	2.4	0.3	<0.1	14-23	19
Antennariidae							
Unidentified Antennariidae	3	2	2.4	1.9	<0.1	16-21	18
Monacanthidae							
Unidentified Monacanthidae	2	2	2.4	1.2	<0.1	17-38	28
Ophidiidae							
Ophidion barbatum	23	2	2.4	1.4	<0.1	32-37	35
Fistulariidae							
Fistularia spp.	2	2	2.4	0.3	<0.1	70-86	78
Triglidae							
Unidentified Triglidae	2	2	2.4	0.5	<0.1	21-22	22
Diretmidae							
Diretmus argenteus	1	1	1.2	3.1	0.1		
Nemichthyidae							
Unidentified Nemichthyidae	1	1	1.2	0.1	<0.1		
Brotulidae							
Unidentified Brotulidae	1	1	1.2	0.8	<0.1		
Trachichthyidae							
Gephyroberyx darwini	1	1	1.2	1.0	<0.1		
Grammicolepididae							
Xenolepidichthys spp.	1	1	1.2	0.3	<0.1		
Caproidae							
Antigonia capros	1	1	1.2	3.1	0.1		
Trachipteroidei							
Unidentified Trachipteroidei	1	1	1.2	0.1	<0.1		
Coryphaenidae							
Coryphaena hippurus	1	1	1.2	0.1	<0.1		
Chaetodontidae							
Unidentified Chaetodontidae	1	1	1.2	0.1	<0.1		
Sphyraenidae							
Sphyraena spp.	1	1	1.2	0.2	<0.1		
Chiasmodontidae							
Dysalotus spp.	1	1	1.2	1.0	<0.1		
Istiophoridae							
Unidentified Istiophoridae	1	1	1.2	0.2	<0.1		
Tetragonuridae							
Tetragonurus cuvieri	4	1	1.2	154.0	6.3	165-183	174
Crustaceans:							
Unidentified Crustacea	--	12	14.5	11.2	0.5		
Stomatopoda							
Unidentified Stomatopoda (larvae)	1,081	63	75.9	161.9	6.6		
Decapoda							
Brachyura (megalopae)	287	19	22.9	31.3	1.3		
Unidentified Raninidae (megalopae)	235	23	27.7	25.1	1.0		
Unidentified Grapsidae (megalopae)	8	2	2.4	1.0	<0.1		

APPENDIX TABLE 2.—Continued.

Taxon	Number of organisms	Frequency of occurrence		Volume		Size (mm)	
		Number	%	ml	%	Range	Mean
Paguridea (all Glaucothoë)							
Dardanus spp.	3	3	3.6	0.3	<0.1		
Dardanus pectinatus	89	11	13.3	9.5	0.4		
Petrochirus sp.	1	1	1.2	0.1	<0.1		
Unidentified Paguridea	10	4	4.8	1.0	<0.1		
Macrura-Natantia							
Caridea							
Unidentified Pandalidae (larvae)	14	6	7.2	3.9	0.2		
Paciphaeu semispinosa	10	1	1.2	4.0	0.2		
Heterocarpus ensifer	1	1	1.2	0.2	<0.1		
Procletes stage (*Heterocarpus ensifer*)	6	3	3.6	0.9	<0.1		
Anisocaris sp. (larval genus)	5	2	2.4	0.5	<0.1		
Eretmocaris sp. (larval genus)	2	2	2.4	0.3	<0.1		
Oplophorus sp. (larval genus)	1	1	1.2	0.1	<0.1		
Enoplometopus antilensis	5	5	6.0	2.0	<0.1		
Unidentified Caridea	16	9	10.8	4.6	0.2		
Macrura-Reptantia (all Phyllosoma stages)							
Scyllarus arctus	5	2	2.4	1.2	<0.1		
Unidentified Macrura-Reptantia	6	3	3.6	0.6	<0.1		
Amphipoda (Hyperiidea)							
Phrosina semilunata	73	29	34.9	14.6	0.6		
Brachyscellus sp.	58	14	16.9	4.8	0.2		
Phronima sedentaria	17	8	9.6	2.0	<0.1		
Oxycephalus clausii	9	6	7.2	0.9	<0.1		
Platyscellus ovoides	1	1	1.2	0.1	<0.1		
Streetsia challengeri	1	1	1.2	0.1	<0.1		
Euphausiacea							
Euphausia hanseni	26	6	7.2	1.3	<0.1		
Mollusks:							
Cephalopoda (adults and juveniles)							
Unidentified Cephalopoda	48	12	14.5	30.7	1.2		
Octopoda							
Argonauta sp.	1	1	1.2	1.5	0.1		
Tremoctopus violaceus	9	1	1.2	4.5	0.2		
Octopus sp.	5	2	2.4	2.8	<0.1		
Unidentified Octopoda	25	12	14.5	31.6	1.3		
Teuthoidea							
Unidentified Ommastrephidae	437	36	43.4	314.2	12.8		
Unidentified Chiroteuthidae	1	1	1.2	1.0	<0.1		
Ornithoteuthis antillarum	5	1	1.2	1.5	<0.1		
Liocranchia reinhardti	11	1	1.2	5.0	0.2		
Liocranchia sp.	1	1	1.2	0.2	<0.1		
Cranchia scabra	3	2	2.4	3.2	0.1		
Onychoteuthis banksi	1	1	1.2	0.4	<0.1		
Mastigoteuthis sp.	1	1	1.2	0.5	<0.1		
Onykia sp.	4	2	2.4	5.5	0.2		
Unidentified Cranchiidae	5	3	3.6	2.8	0.1		
Unidentified Enoploteuthidae	4	3	3.6	1.7	<0.1		
Unidentified Teuthoidea	204	45	54.2	124.6	5.1		
Gastropoda							
Unidentified Atlantidae	2	2	2.4	0.2	<0.1		
Miscellaneous:							
Salpidae	27	17	20.5	8.8	0.4		

APPENDIX TABLE 3.—List of forage organisms fond in stomachs from 202 skipjack tunas, collected off the west coast of Africa during cruise UN6802. Number of organisms, frequency of occurrence, and percentage of total volume are given for each taxon. Size ranges and mean sizes are given only for certain forage fishes. Fishes are listed in decreasing order of frequency of occurrence by families; crustaceans, mollusks, and miscellaneous groups are listed by broad categories.

Taxon	Number of organisms	Frequency of occurrence		Volume		Size (mm)	
		Number	%	ml	%	Range	Mean
Fishes:							
Unidentifiable	698	155	76.7	109.3	11.1		
Paralepididae							
Unidentifiable Paralepididae	1,026	59	29.2	280.5	28.4	52-112	68
Carangidae							
Vomer setapinnis	44	33	16.3	24.0	2.4	9-36	27
Trachinotus ovatus	4	4	2.0	0.6	0.1	17-23	19
Unidentified Carangidae	15	13	6.4	6.0	0.6	11-56	22
Gempylidae							
Gempylus serpens	1	1	0.5	0.3	0.1		
Unidentified Gempylidae	25	17	8.4	11.9	1.2	62-94	78
Trichiuridae							
Unidentified Trichiuridae	49	18	8.9	13.6	1.4	66-110	94
Scombridae							
Auxis spp.	33	10	5.0	8.6	0.9	15-63	31
Sarda sarda	4	4	2.0	2.3	0.2	25-43	34
Scomber japonicus	1	1	0.5	1.3	0.1		
Serranidae							
Unidentified Serranidae	152	12	5.9	15.0	1.5	14-25	19
Scorpaenidae							
Unidentified Scorpaenidae	13	10	5.0	2.6	0.3	15-25	18
Lutjanidae							
Unidentified Lutjanidae	9	7	3.5	1.4	0.1	15-24	19
Berycoidei							
Unidentified Berycoidei	8	8	4.0	1.4	0.1	13-17	15
Percoidei							
Unidentified Percoidei	257	6	3.0	85.1	8.6	19-32	27
Anguilloidei							
Unidentified Leptocephalus	6	5	2.5	0.7	0.1		
Bothidae							
Unidentified Bothidae	7	5	2.5	1.1	0.1	20-30	25
Acanthuridae							
Unidentified Acanthuridae	4	4	2.0	0.8	0.1	13-17	15
Trachipteridae							
Trachipterus trachypterus	4	4	2.0	2.6	0.3		
Triglidae							
Unidentified Triglidae	5	5	2.5	1.2	0.1	17-23	20
Chaetodontidae							
Chaetodon spp.	4	3	1.5	2.3	0.2	12-35	23
Clupeoidei							
Unidentified Clupeoidei	70	3	1.5	4.7	0.5		
Syngnathidae							
Unidentified Syngnathidae	2	2	1.0	0.7	0.1	100-113	106
Synodontidae							
Unidentified Synodontidae	14	2	1.0	2.0	0.2		
Alepisauridae							
Alepisaurus ferox	1	1	0.5	3.6	0.4		
Holocentridae							
Unidentified Holocentridae	1	1	0.5	0.5	0.1		
Ophidiidae							
Unidentified Ophidiidae	2	2	1.0	1.4	0.1		
Priacanthidae							
Priacanthus spp.	1	1	0.5	0.2	<0.1		
Stromateoidei							
Unidentified Stromateoidei	2	1	0.5	2.5	0.2	23-53	38
Tetraodontidae							
Unidentified Tetraodontidae	1	1	0.5	0.1	<0.1		
Uranoscopidae							
Uranoscopus spp.	1	1	0.5	0.8	0.1		

APPENDIX TABLE 3.—Continued.

Taxon	Number of organisms	Frequency of occurrence		Volume		Size (mm)	
		Number	%	ml	%	Range	Mean
Crustaceans:							
Amphipoda (Hyperiidea)							
Phrosina semilunata	561	139	68.8	83.8	6.2		
Brachyscellus spp.	281	94	46.5	18.9	1.4		
Phronima sedentaria	39	26	12.9	4.3	0.3		
Anchylomera blossevillei	27	3	1.5	1.2	<0.1		
Platyscellous ovoides	9	6	3.0	0.7	<0.1		
Vibilia armata	6	6	3.0	0.6	<0.1		
Platyscellus serratulus	2	2	1.0	0.4	<0.1		
Platyscellus armatus inermis	1	1	0.5	0.2	<0.1		
Oxycephalus clausi	1	1	0.5	0.1	<0.1		
Decapoda							
Raninidae (megalopae)	112	58	28.7	9.0	0.7		
Brachyura (megalopae)	16	13	6.4	1.9	0.1		
Stomatopoda (larval forms)	43	31	15.3	5.4	0.4		
Euphausiacea							
Euphausia hanseni	3,556	19	9.4	118.0	8.8		
Anomura							
Paguridea (all Glaucothoë)							
Dardanus pectinatus	9	7	3.5	0.9	<0.1		
Macrura-Reptantia (all Phyllosomae larvae)							
Scyllarus arctus	5	5	2.5	0.9	<0.1		
Scyllarus sp.	2	2	1.0	0.2	<0.1		
Scyllarides sp.	1	1	0.5	0.1	<0.1		
Macrura-Natantia							
Sergestidae	1	1	0.5	0.2	<0.1		
Lucifer sp.	1	1	0.5	0.1	<0.1		
Caridea	1	1	0.5	0.1	<0.1		
Palaemonidae	1	1	0.5	0.1	<0.1		
Copepoda							
Arietellus armatus	1	1	0.5	0.1	<0.1		
Candacia varicans	1	1	0.5	0.1	<0.1		
Unidentifiable Crustacea				0.9	<0.1		
Mollusks:							
Cephalopoda (adults and juveniles)							
Unidentified Cephalopoda	14	13	6.4	3.2	0.2		
Octopoda							
Argonauta sp.	2	2	1.0	6.7	0.5		
Other Octopoda	1	1	0.5	0.1	<0.1		
Teuthoidea							
Ornithoteuthis antillarum	78	33	16.3	126.4	10.1		
Ommastrephidae	37	31	15.3	9.4	0.7		
Unidentified Teuthoidea	4	3	1.5	0.3	<0.1		
Gastropoda							
Pteropoda							
Cavolinia longirostris	39	12	5.9	1.8	<0.1		
Heteropoda							
Atlantidae	4	4	2.0	0.3	<0.1		
Atlanta sp.	2	2	1.0	0.2	<0.1		
Atlanta peroni	1	1	0.5	0.1	<0.1		
Oxygyrus keraudreni	1	1	0.5	0.1	<0.1		
Miscellaneous:							
Salpidae	8	7	3.5	1.1	<0.1		

APPENDIX TABLE 4.—List of forage organisms found in stomachs from 43 yellowfin tunas, collected off the west coast of Africa during cruise UN6802. Number of organisms, frequency of occurrence, and percentage of total volume are given for each taxon. Size ranges and mean sizes are given only for certain forage fishes. Fishes listed in decreasing order of frequency of occurrence; crustaceans, mollusks, and miscellaneous groups are listed by broad categories.

Taxon	Number of organisms	Frequency of occurrence		Volume		Size (mm)	
		Number	%	ml	%	Range	Mean
Fishes:							
Unidentifiable	238	38	88.4	61.1	17.1		
Scombridae							
Auxis spp.	53	11	25.6	7.4	2.1	15-34	22
Sarda sarda	4	2	4.7	0.5	0.1	15-21	18
Scomber japonicus	1	1	2.3	0.1	<0.1		
Unidentified Scombridae	15	6	14.0	0.8	0.2		
Carangidae							
Vomer setapinnis	14	10	23.3	4.5	1.2		
Unidentified Carangidae	3	3	7.0	5.3	1.5	21-98	48
Paralepididae							
Unidentified Paralepididae	10	5	11.6	2.1	0.6		
Gempylidae							
Gomyplus serpens	3	3	7.0	0.4	0.1		
Unidentified Gempylidae	2	1	2.3	0.1	<0.1		
Trichiuridae							
Unidentified Trichiuridae	4	3	7.0	2.1	0.6		
Chaetodontidae							
Chaetodon spp.	2	2	4.7	2.5	0.7	20-35	27
Exocoetidae							
Cypselurus spp.	1	1	2.3	27.5	7.7		
Unidentified Exocoetidae	1	1	2.3	7.0	1.9		
Percoidei							
Unidentified Percoidei	16	2	4.7	5.0	1.4	20-28	24
Trachipteridae							
Trachipterus trachypterus	3	2	4.7	9.2	2.6		
Alepisauridae							
Alepisaurus ferox	1	1	2.3	20.0	5.6		
Bothidae							
Unidentified Bothidae	1	1	2.3	0.1	<0.1		
Ophidiidae							
Unidentified Ophidiidae	1	1	2.3	2.0	0.6		
Syngnathidae							
Unidentified Syngnathidae	1	1	2.3	0.3	0.1		
Crustaceans:							
Stomatopoda (larval forms)	81	24	55.8	7.4	2.1		
Amphipoda (Hyperiidea)							
Phrosina semilunata	62	19	44.2	9.4	2.6		
Brachyscelus spp.	8	6	13.9	0.7	1.9		
Phronima sedentaria	5	4	9.3	1.3	3.6		
Vibilia armata	1	1	2.3	0.1	0.1		
Decapoda							
Brachyura (megalopae)	13	4	9.3	1.7	0.5		
Raninidae (megalopae)	5	4	9.3	0.4	0.1		
Anomura							
Macrura-Reptantia (all phyllosemae larvae)							
Scyllaridae sp.	2	2	4.6	0.2	0.1		
Scyllarus sp.	2	2	4.6	0.2	<0.1		
Paguridea (all Glaucothoë)							
Dardanus pectinatus	4	2	4.6	0.4	1.1		
Unidentifiable Crustacea				0.4	1.1		
Mollusks:							
Cephalopoda (adults and juveniles)							
Unidentified Cephalopoda	7	6	13.9	3.5	1.0		
Octopoda							
Argonauta argo	6	5	11.6	165.5	46.3		
Teuthoidea							
Ommastrephidae	10	2	4.6	4.6	1.3		
Ornitheteuthis antillarum	2	2	4.6	1.3	0.4		
Tetrenychoteuthis dusumieri	1	1	2.3	1.3	0.4		
Unidentified Teuthoidea	4	4	9.2	0.4	1.1		
Miscellaneous:							
Salpidae	4	3	6.9	0.3	0.1		

FOOD HABITS OF JUVENILE MARINE FISHES: EVIDENCE OF THE CLEANING HABIT IN THE LEATHERJACKET, *OLIGOPLITES SAURUS*, AND THE SPOTTAIL PINFISH, *DIPLODUS HOLBROOKI*

WILLIAM E. S. CARR AND CLAYTON A. ADAMS[1]

ABSTRACT

Quantitative gravimetric analyses of stomach contents of juvenile leatherjacket, *Oligoplites saurus*, and spottail pinfish, *Diplodus holbrooki*, have revealed that both species pass through a stage in which they clean ectoparasites from other fishes. This cleaning stage is most evident in juveniles between 26 and 40 mm standard length and is far less evident among juveniles of larger or smaller size. These findings represent the first report that cleaning is practiced by either species and the first quantitative data on the significance of the cleaning habit to members of the Family Carangidae and Family Sparidae. Neither *O. saurus* nor *D. holbrooki* depend exclusively on cleaning as a source of food. Juveniles of *O. saurus* feed heavily on plankton and small shrimp whereas juveniles of *D. holbrooki* feed heavily on epiphytic algae, plankton, and encrusting organisms. Juveniles of both species exhibit distinct changes in diet during growth.

The important role of the estuarine zone in providing nursery areas utilized by the juvenile stages of a large number of marine fishes is now well documented (Sykes and Finucane, 1966; Smith, Swartz, and Massmann, 1966; and others). Although much is known about the food habits of the adults and subadults of most estuarine-dependent species, only a limited literature exists on the food habits of the smaller juvenile individuals. Consequently, we have been studying the food habits of juveniles of all available species of fishes which inhabit certain nursery areas in the nearshore estuarine zone between the Crystal River and the Withlacoochee River on the northwest coast of Florida. To date our study involves 18 species which we are studying concurrently.

In the course of the investigation described above, we have discovered that juveniles of two species, the leatherjacket, *Oligoplites saurus* (Bloch and Schneider) (a carangid), and the spottail pinfish, *Diplodus holbrooki* (Bean) (a sparid), clean ectoparasites from other fishes. This phenomenon has not been reported previously for either species. The report which follows describes the diets of juveniles of both species and shows that these diets include considerable amounts of ectoparasites and other material obtained by cleaning.

MATERIALS AND METHODS

DESCRIPTION OF STUDY AREA AND SAMPLING METHODS

Specimens of juvenile *Oligoplites saurus* and *Diplodus holbrooki* were collected in the vicinity of the Florida Power Corporation steam electric station located 7.5 miles northwest of the town of Crystal River, Fla. (lat 23°57'N, long 82°45'W). This station is situated approximately 3 miles northwest of the mouth of the Crystal River and 4 miles southeast of the mouth of the Withlacoochee River on the northwest coast of Florida. Sampling sites in this estuarine area were located to the north and south of the dikes delimiting the intake canal of the electric station. The sampling sites were densely vegetated with seagrasses, primarily *Ruppia maritima* and *Diplanthera wrightii*, and several

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types of algae among which two species of *Caulerpa, C. prolifera* and *C. paspaloides*, were most conspicuous. Collections of fishes were made near low tide at which time the depth at the sampling sites was 3 to 4 ft. Specimens analyzed for this report were collected from April 3 to August 25, 1971. Water temperatures at the sampling sites during this period ranged from 17.3° to 33.1°C whereas salinities ranged from 16.4 to 24.1 ‰. All sampling sites were greater than a mile from the zone of influence of thermal discharge from the electric station.

The majority of juvenile fishes used in this study were collected with a bag seine (50 ft × 6 ft) constructed of ⅜-inch stretched mesh netting. A few specimens were collected in a 5-ft cast net constructed of ½-inch stretched mesh netting. Specimens were preserved immediately in 20% Formalin-seawater. In the laboratory, fish were washed in tap water, sorted to species, and stored in 75% isopropyl alcohol. High concentrations of preservative were used to assure adequate preservation of stomach contents. Specimens of adult *D. holbrooki* were collected with hook and line, injected immediately with Formalin, and treated as above.

ANALYSIS OF STOMACH CONTENTS

Juvenile fishes were measured to the nearest 1.0 mm standard length and sorted into size classes of 5-, 10-, or 20-mm increments depending on the number of fish available. All references to fish length are in terms of standard length. After removal of stomachs, food items were removed in alcohol with the aid of a dissecting microscope. Stomach contents from similar size classes were pooled and analyzed as to percent composition using a modified gravimetric procedure which employed a preliminary fractionation of food items with a series of sieves. This procedure is outlined below:

1. Large food items of similar types easily recognizable to the naked eye were removed onto preweighed filter pads (Whatman[2] No. 42, 2.5-inch diameter). This initial step was used only for certain food items (i.e., shrimp, crabs, larval fish, etc.) obtained from fish in the larger size classes.
2. The remaining stomach contents were poured into a series of 3-inch diameter sieves (U.S. Standard Nos. 10, 20, 30, 60, 120, 200) arranged and clamped together in order of decreasing mesh size. Sieves Nos. 10 and 20 were frequently not needed for fractionations of material from fish in very small size classes.
3. The series of sieves was secured to a Burrell "Wrist Action" shaker and shaken gently for 10 to 15 min while washing continuously under slowly flowing water.
4. The contents of each sieve (comprising a sieve fraction) was washed into a finger bowl for detailed analysis beneath a dissecting microscope. Analysis involved adding five large drops of the sieve fraction to a gridded petri dish (13 squares per inch) and recording the frequency of occurrence of each type of food item in each drop. The accuracy of this method is good because all food items in a particular sieve fraction are of comparable size. The portion of the contents of each sieve fraction attributable to each type of food item was recorded.
5. After analysis of all sieve fractions, each fraction was vacuum-filtered onto a separate preweighed filter pad using a Millipore filter holder and a vacuum flask.
6. Filter pads were dried overnight in a drying oven (ca. 70°C) and dry weights of food items were calculated after weighing the pads to the nearest 0.0001 g on a microbalance.

Further comments on the efficacy of this procedure for analyzing the stomach contents of small fish are given in the following section on Results.

RESULTS

OLIGOPLITES SAURUS

Figure 1 shows the results of analyses of stomach contents of juvenile *O. saurus* belonging

[2] Reference to trade names in this publication does not imply endorsement of commercial products by the National Marine Fisheries Service.

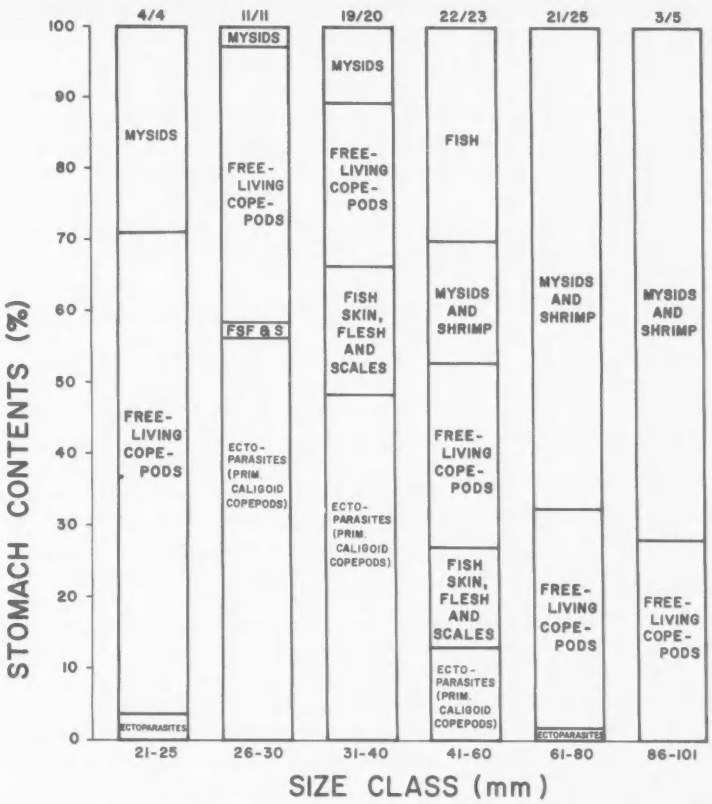

FIGURE 1.—Stomach contents of juveniles of *Oligoplites saurus*. Bar graph for each size class shows percent of total stomach contents attributable to individual food items. Designation of sample size above each bar graph shows fraction of stomachs analyzed which contained food.

to the six size classes obtained in our collections. Juveniles of this species go through a stage in which ectoparasites of fish make a major contribution to their diet. The relative contribution of ectoparasites to the diet is at a maximum in fish that are betweeen 26 and 40 mm long. Ectoparasites account for approximately 56% of the stomach contents of fish 26 to 30 mm long and approximately 48% of the contents of fish 31 to 40 mm long. The majority of the ectoparasites consumed were caligoid copepods; a few were branchiurans, *Argulus* sp. In contrast, ectoparasites constituted only 2 to 4% of the stomach contents in fish less than 26 mm long or greater than 60 mm long. Ectoparasites made up less than 1% of the stomach contents of fish 86 to 100 mm long.

The importance of food material obtained by cleaning in juveniles of this species is even greater if the contribution of bits of fish skin, flesh, and scales is combined with that of ectoparasites (see Figure 1). In leatherjackets between 26 and 60 mm in length, the total portion of the stomach contents attributable to material

obtained from cleaning ranges from 27 to 67% with maximum percentages obtained in 26 to 40 mm fish (58 to 67%).

Most of the fish skin, flesh, and scales present in the stomachs are construed to have come from cleaning activities, since other than occasional fish larvae, fish per se were seldom encountered in any of the stomachs examined.

A sizable portion of the diet of juveniles of all size classes consists of free-living organisms, primarily copepods, mysids, and small shrimp (see Figure 1). Free-living organisms account for 96 to 100% of the stomach contents of juveniles outside the 26 to 60 mm size classes. Free-living copepods comprise the major food item of 21 to 25 mm individuals whereas mysids and small shrimp made up the major food items of fish in the 61 to 100 mm size classes.

Since there were no prior reports on *O. saurus* functioning as a cleaner, additional analyses were made of other specimens collected from other sites at other times. Collections of juvenile *O. saurus* were obtained from Dr. Carter R. Gilbert of the Florida State Museum for this purpose. The results of analyses of these collections are given in Table 1. Ectoparasites were present in the stomachs of fish belonging to all size classes examined. The relative contribution of ectoparasites to the diet was again maximum in fish between 26 and 40 mm in length. A maximum of 24 ectoparasites was recovered from each of two stomachs of fish 41 to 60 mm long. The relative contribution of ectoparasites to the total diet decreased dramatically in fish greater than 60 mm in length. The data from analyses of museum collections correlated remarkably well with the data presented earlier on freshly collected specimens. The lower percentages of stomach contents attributable to ectoparasites in the museum collections may have been due to the fact that these fish had been stored for 10 to 20 years and were not as well preserved as our freshly collected specimens. This was suggested by the presence of significant amounts of unidentifiable debris in the stomachs of the museum fish.

DIPLODUS HOLBROOKI

Figure 2 shows the results of analyses of stomach contents of juvenile *D. holbrooki* in the 10 size classes obtained in our collections. As was the case with *O. saurus*, *D. holbrooki* goes through a juvenile stage in which it is a cleaner. One or more species of the ectoparasitic branchiuran, *Argulus*, is significant in the diet of juveniles between 21 and 50 mm in length. The percentage of ectoparasites in the total stomach contents is maximum in fish 31 to 35 mm long (20%) with somewhat smaller percentages recorded in fish 26 to 30 mm long and in fish 36 to 40 mm long. A maximum of 16 ectoparasites (*Argulus*) was recovered from the stomach of a single fish in the 36 to 40 mm size class. The relative contribution of ectoparasites to the total stomach contents decreases dramatically to less than 1% in fish less than 61 mm long. Only one ectoparasite was found in the stomachs of 35 fish 61 to 70 mm long. Ectoparasites were absent from the stomachs of fish less than 21 mm or greater than 70 mm in length. Likewise, ectoparasites were absent from the stomachs of 18

TABLE 1.—Analyses of stomach contents of *Oligoplites saurus* obtained from Florida State Museum.[1]

Size class (mm)	Number of fish	Number of stomachs with food	Stomachs with food and ectoparasites		Number of ectoparasites per stomach with food		Ectoparasites - % of total stomach contents
			Number	Percent	Average	Range	
21-25	2	1	1	100	2	(2)	Not determined
26-30	5	5	4	80	1.4	(0-3)	26
31-40	12	11	9	82	4.1	(0-9)	21
41-60	23	21	19	90	6.8	(0-24)	13
61-80	15	15	13	87	3.1	(0-12)	3
81-100	7	7	3	43	0.4	(0-1)	0.3

[1] Fish taken from collections indicated as follows:
Cedar Key, Fla., 10/27/47, 7/24/48, 10/24/48, 9/25/53.
Little Gasparilla Pass, Charlotte Co., Fla., 7/21/60.

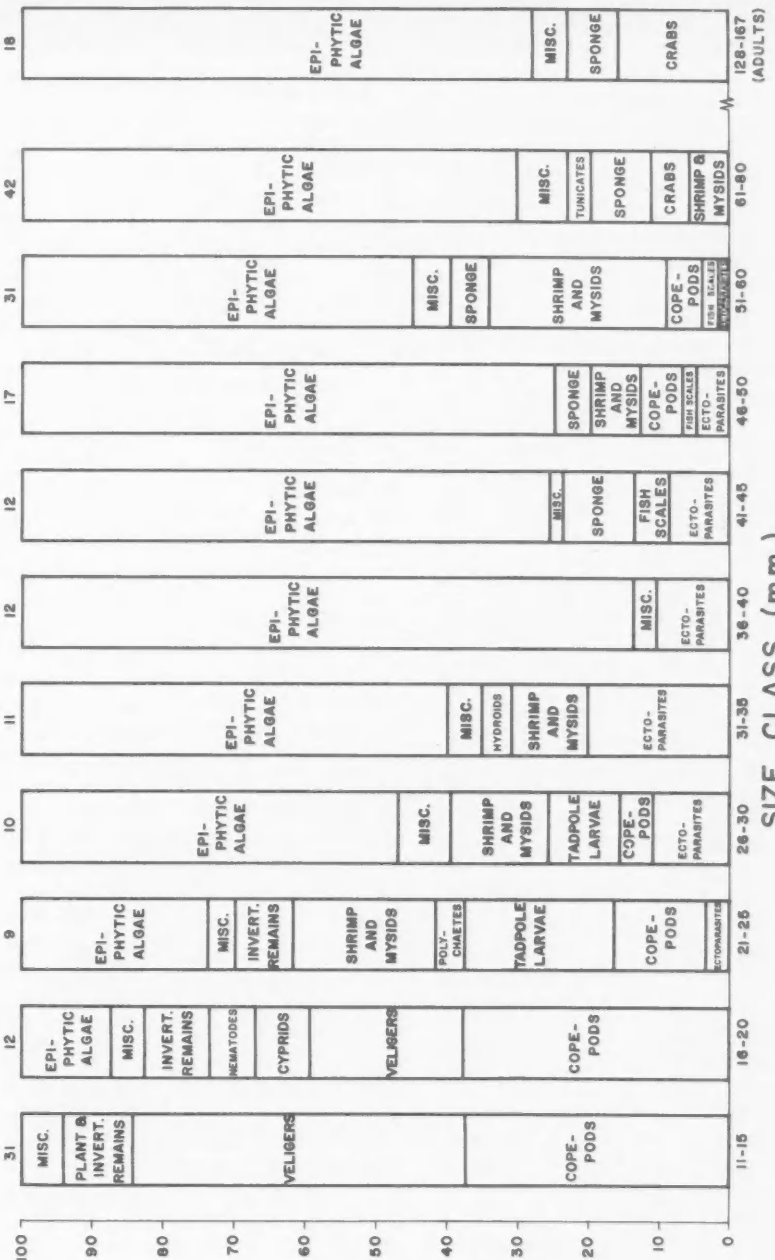

FIGURE 2.—Stomach contents of juveniles of *Diplodus holbrooki*. Presentation same as in Figure 1. Sample size above each bar graph shows number of stomachs with food which were analyzed. Misc. = combination of all items which individually account for less than 3% of total.

adult *Diplodus* which were analyzed. Fish scales were a common constituent of stomachs of fish in size classes between 21 and 70 mm in length. The contribution of fish scales to the stomach contents was at a maximum in 41 to 45 mm fish (5%). The majority of the fish scales present in stomachs are construed to have come from cleaning activities since fish per se were seldom encountered in the stomachs of any of the *Diplodus* examined.

As shown in Figure 2, the bulk of the diet of juvenile *D. holbrooki* consists of free-living animals and epiphytic algae. Cleaning activities provide only a modest portion of the total food ingested by fish in any of the size classes. Individuals in size classes between 11 and 25 mm are primarily planktivorous with veligers, copepods, tunicate tadpole larvae, mysids, and small shrimp accounting for 56 to 87% of the total stomach contents. Fish over 25 mm become very dependent on plant material in the form of epiphytic algae. This plant material accounts for 53 to 87% of the total stomach contents of all size classes above 26 mm in length, including adults. However, variable amounts of animal material, especially sponge, copepods, shrimp, and mysids, are also consumed. Stomach contents of fish greater than 25 mm in length show that *Diplodus* feeds heavily on plant and animal material which grows attached to other subjects. Even the crabs consumed by larger individuals are primarily porcellanids (*Petrolisthes* sp.) that live in association with submerged rock and shell.

Since there are no prior reports of *D. holbrooki* functioning as a cleaner, additional juvenile specimens were obtained from Dr. Carter R. Gilbert. These specimens were collected in 1951 and 1957 near Cedar Key, Fla. Unfortunately, the museum collections were short on specimens in the 21 to 60 mm size range and those that were provided did not have well-preserved stomach contents. All that can be stated with certainty from these specimens is that ectoparasites did appear in stomachs of 5 of the 13 fish available in the size range of 26-35 mm. Representatives of other juvenile size classes were either not available or inadequately preserved for analysis.

EFFICACY OF SIEVE FRACTIONATION PROCEDURE

The sieve fractionation procedure described in Materials and Methods has contributed greatly to our capacity to analyze quantitatively the stomach contents of very small fish. This procedure provides a convenient means of separating a heterogeneous mixture of minute food items into fractions which are individually quite homogeneous with respect to particle size. Table 2 presents the format used and the results obtained following a sieve fractionation of stomach contents of *D. holbrooki* belonging to the 11 to 15 mm size class. This table and the following discussion are provided to illustrate the efficacy of this procedure. After identification of the food items in each sieve fraction (Column A), the determination of the portion of each fraction attributable to a particular food item (Column B) is eased considerably by the fact that all items in the fraction are of comparable size. After determining the dry weight of each fraction (Column C), the contribution of individual food items (Column D) is estimated by multiplying the weight of the fraction by the value defining the portion of the fraction attributable to that food item. Finally, the total amounts and percentages of the entire stomach contents which are attributable to the individual food items are determined by simple compilation (Columns E and F). This procedure has now been employed in this laboratory to analyze the stomach contents of juvenile stages of 18 species of fishes.

DISCUSSION

Randall (1967) has described the Carangidae as a family of carnivorous fish whose food habits may be divided into three major categories: fish feeders, plankton feeders, and mollusk feeders. His classification was based primarily on feeding habits of adult fish, and it was recognized that not all of the species, including their juvenile stages, fit perfectly into these categories. Randall analyzed stomach contents of *Oligoplites saurus* (149 to 234 mm) from the West Indies and found this carangid to be primarily a fish feeder. Similar findings have been reported by

TABLE 2.—Data obtained from sieve fractionation and gravimetric analysis of stomach contents of 31 juvenile *D. holbrooki* in 11-15 mm size class.

Sieve mesh size[1]	(Col. A) Food item	(Col. B) Portion of Sieve fraction attributable to food item	(Col. C) Dry weight of entire sieve fraction (mg)	(Col. D) Calculated weight of food item (mg)
No. 60-250 μ	Copepods	0.47	3.5	1.6
	Veligers	0.38		1.3
	Cyprids	0.07		0.3
	Nematodes	0.07		0.3
No. 120-125 μ	Copepods	0.40	3.2	1.3
	Veligers	0.60		2.0
	Nematodes	<0.01		<0.1
No. 200-74 μ	Copepods (larval)	0.17	2.2	0.4
	Veligers	0.43		0.9
	Animal remains	0.22		0.5
	Plant remains	0.17		0.4

Summarization of data:

Food item	(Col. E) Total dry weight (mg)	(Col. F) Percent of total sample
Copepods	3.3	37
Veligers	4.2	47
Cyprids	0.3	3
Nematodes	0.3	3
Animal remains	0.5	6
Plant remains	0.4	4
Total	9.0	100

[1] A No. 30 sieve (595 μ) also used in sieve series employed here, but it retained none of the items consumed by 11- to 15-mm fish.

Beebe and Tee-Van (1928) on specimens from Haiti and by Springer and Woodburn (1960) on specimens from Tampa Bay, Fla. Tabb and Manning (1961) reported that this species (30 to 120 mm) in Florida Bay feeds heavily on snapping shrimp and small pink shrimp in addition to fish larvae. With the exception of the modest data presented by Randall (1967), the literature is devoid of quantitative information on the food habits of this common inshore species. No prior reports have been made on this species acting as a cleaner.

Our quantitative determinations of the stomach contents of juvenile *O. saurus* (21 to 80 mm) collected near Crystal River, Fla., show clearly that this carangid passes through a stage in the initial year of its development in which intensive cleaning behavior is implicated. Food materials obtained from cleaning activities, especially caligoid copepods, account for 58 to 67% of the stomach contents of fish 26 to 40 mm in length (see Figure 1). Lesser amounts of such material were present in fish outside of this size range. Although no observations were made of *Oligoplites* actually engaged in cleaning activities in the field, it is extremely unlikely that any other type of feeding activity can account for these results. If ectoparasites, such as caligoid copepods, were readily ingested from the plankton, then they would be expected to be common in the stomachs of the planktivorous stages of other species of fishes in the area. We have analyzed the stomachs of more than 6,000 juvenile fishes belonging to 18 species present in our study area and, aside from a single *Argulus* sp. found in the stomachs of one *Orthopristes chrysopterus* and one *Menidia beryllina*, have found no ectoparasites or other indicators of cleaning activity in species other than *O. saurus* and *D. holbrooki*. The only other reports of cleaning behavior among the carangids are brief accounts given by divers on the pilotfish (*Naucrates ductor*) and young bar jack (*Caranx ruber*) (Hass, 1953; Randall, 1962).

Although many studies have been done on various aspects of the biology of members of the Family Sparidae, the literature contains only one very brief account of an apparent cleaning

episode involving a member of this family. Breder (1962) noted a single juvenile *Lagodon rhomboides* picking at the pelvic axils of three successive *Mugil cephalus* in Lemon Bay, Fla. Breder commented that this was the only time he had observed this interaction although he was thoroughly familiar with both species.

Our analyses of stomach contents of juvenile *D. holbrooki* (11 to 80 mm, see Figure 2) show clearly that this species, like *O. saurus*, goes through a stage in the initial year of its development in which cleaning behavior is implicated. Concurrent analyses of more than 3,000 stomachs of juveniles of another sparid, *Lagodon rhomboides* (10 to 130 mm), collected from the same area failed to yield a single ectoparasite or other evidence of cleaning activity in this related species. Data on food habits of *L. rhomboides* and juveniles of other species in our study area will be published at a later date.

It is noteworthy that, in juveniles of both *D. holbrooki* and *O. saurus*, fishes in the size range of 26 to 40 mm are the ones in which ectoparasites make their maximum contribution to the diet. Likewise, ectoparasites become markedly less important in the diets of slightly larger individuals thereby strongly implying that the cleaning habit is confined to only a portion of the total juvenile phase of development in both species. Although our data show that the diet of juvenile *O. saurus* includes proportionately greater amounts of material obtained from cleaning activities than the diet of juvenile *D. holbrooki*, it is clear that neither species depends exclusively on this activity. Limbaugh (1961) has previously reported that some species are cleaners only as juveniles and that few cleaners depend exclusively on this habit as a source of food.

Our analyses of stomach contents of *D. holbrooki* show that after reaching a length of 26 to 30 mm, this species becomes very dependent on plant material in the form of epiphytic algae. Reid (1954) found algae as well as other items in the stomachs of *D. holbrooki* from Cedar Key, Fla.; however, neither the size of the individuals analyzed nor any sort of quantitative information was reported. The study of Caldwell (1955) on this species from the same area included no information on stomach contents. Randall (1967) has reported that the diet of the closely related species, *D. caudimacula*, from the West Indies is approximately 80% algae, thereby making it quite similar in this regard to our findings with *D. holbrooki*.

Although our studies on fishes, collected in the field and obtained from museum collections, show clearly that juveniles of both *O. saurus* and *D. holbrooki* are cleaners, attempts to observe cleaning behavior in the field have been unsuccessful. The estuarine water in our study area is too turbid to permit underwater observations of the behavior of small fish at a distance. Aside from the excellent studies of Limbaugh (1964) and Hobson (1971) on cleaning symbiosis among inshore fishes of southern California, there have been few reports on visual observations of cleaning behavior by fishes in waters of the Temperate Zone. McCutcheon and McCutcheon (1964) alluded to the fact that water conditions in the Temperate Zone are frequently less favorable than those in the tropics where many detailed descriptions of cleaning symbiosis have been made. On two occasions, we observed groups of pinfish (*Lagodon rhomboides*) in our study area behaving in a manner suggestive of that described for groups of blacksmith (*Chromis punctipinnis*) when presenting themselves to a cleaner (Limbaugh, 1964; Feder, 1966; and Hobson, 1971). On both occasions, a group of several dozen subadult pinfish were seen milling about in a tight circle just beneath the surface in water approximately 6 ft deep. Pinfish are normally bottom dwellers, and the sight of a large group near the surface behaving as described above was extremely unusual. Although sizable numbers of juvenile *D. holbrooki* were seen swimming back and forth in the vicinity of the pinfish, poor visibility made it impossible to determine whether the pinfish were being cleaned. Juvenile *Diplodus* collected from this same area at this time were found to have ectoparasites (primarily *Argulus*) in their stomachs. In addition, it may be noteworthy that juveniles of *D. holbrooki* and of *L. rhomboides*, both sparids, are frequently seen swimming together in small mixed schools.

Although no observations have been made of

suggestive interspecific associations of *O. saurus*, the notes of Breder (1942) on the unusual "leaf-mimic" behavior of juveniles of this species may well be related to its cleaning behavior. Likewise the potent sting associated with the dorsal and anal spines, and the exaggerated size of these spines in juveniles (Breder, 1942), is likely to be an adaptation providing a degree of immunity from predation in this species. *Oligoplites* has not been found in the stomachs of any of the fishes we have examined even though juveniles of this species are very common in the area. We are currently investigating a change in dentition, quite likely related to the cleaning habit, which is exhibited by this species. Juveniles have an outer row of closely fitting, distinctly flattened, incisorform teeth which are seemingly well adapted to the task of scraping or of tearing objects from surfaces. In adults these teeth are more widely separated and caniform.

Limbaugh (1961) and Feder (1966) have generalized that cleaners in the Temperate Zone tend to be more gregarious and less brightly colored or contrastingly marked than cleaners in tropical waters. These generalizations have been criticized by Hobson (1969). Field observations of juveniles of both *O. saurus* and *D. holbrooki* reveal that both species are gregarious and swim about in small schools of frequently several dozen individuals. Whereas *O. saurus* is a rather unspectacular dull olive color, *D. holbrooki* possesses a bright silver sheen with a large pronounced black spot on the caudal peduncle. Hence the characteristics of these two cleaners from temperate waters provide both support and dissent to the generalizations of Limbaugh and Feder. Since *O. saurus* is also found in tropical waters, evidence of cleaning activity there would result in this species being ranked among the most unspectacularly colored of the tropical cleaners.

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COMPARISON OF VARIOUS ALLOMETRIC RELATIONSHIPS IN INTERTIDAL AND SUBTIDAL AMERICAN OYSTERS[1]

RICHARD F. DAME[2]

ABSTRACT

The allometric relationships for the possible combinations of whole weight, dry body weight, soft body weight, shell weight, height, and length were computed for intertidal and subtidal South Carolina oysters. All relationships between intertidal and subtidal oysters involving dry body weight were significantly different. The percent moisture in the tissues was 81.1% for subtidal oysters and 83.4% for intertidal oysters and did not vary with size. Height appears to be the most useful parameter for predicting other biomass parameters from field data.

The American oyster, *Crassostrea virginica* (Gmelin), is one of the principal biomass components of many southeastern estuarine ecosystems, especially that of the North Inlet Estuary, Georgetown, S.C. (Figure 1). This study of intertidal and subtidal oysters was undertaken for two principal reasons: first, quantitative estimates of various oyster biomass parameters from linear or weight measurements would facilitate secondary productivity studies; second, comparison of the morphology of intertidal and subtidal oysters from a quantitative view would give a more exact meaning to the observed differences between the two forms.

Wilbur and Owen (1964) have noted that the size relations between an intact organism and one of its parts or between two of its parts over a wide size range can usually be expressed by an allometric equation or a power function of the following form:

$$Y = aX^b. \quad (1)$$

Y is some measure of a part, X is a measure of the whole body or another part, and a and b are constants. Equation (1) can be expressed in linear form by a logarithmic transformation as:

$$\log Y = \log a + b \log X. \quad (2)$$

The fitted coefficients, a and b, can easily be determined from a set of data using least-squares regression techniques.

MATERIALS AND METHODS

On March 21, April 11, May 2, July 25, October 3, and December 5, 1970, groups of intertidal and subtidal (1 m below mean low water) oysters were collected from the North Inlet area. Individual oysters were separated from clumps and scrubbed with a wire brush to remove fouling organisms. The whole live weight of an individual oyster was determined to the nearest 0.01 g and varied from 1.70 to 105.50 g. The oysters were then opened, the whole bodies and shells were separated from each other, and each was dried to a constant weight in an oven at 60°C. On May 31 and July 25, the weight of each soft body was determined, and the long and short axes of each shell were measured to the nearest 0.1 mm with vernier calipers.

The statistical treatments used in this study follow the methods of Steel and Torrie (1960), and the computations were carried out on an IBM 7040 computer.[3]

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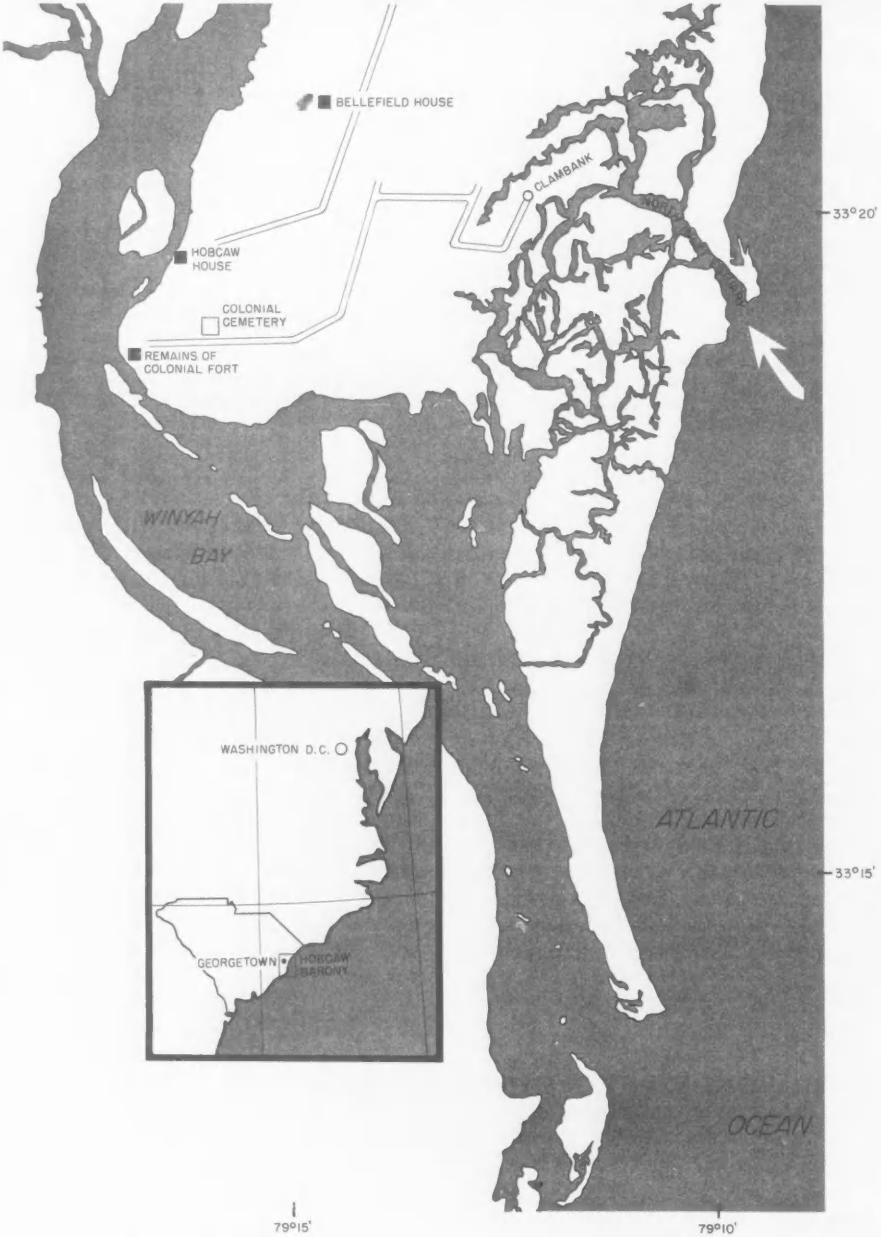

FIGURE 1.—A map showing the location of North Inlet near Georgetown, S.C.

RESULTS

Table 1 gives the allometric coefficients for Equation (2) which best fitted the observed data for the various morphological relationships. The 95% Confidence Intervals (C.I.) are included for log a and b in order to allow an indirect comparison of these values for intertidal and subtidal oysters. The coefficients of a pair of equations were considered significantly different only if the range of log a or b ± its 95% C. I. did not overlap. In addition, Table 1 gives the number of pairs of data used (n) and the coefficient of determination (r^2) which gives an estimate of how well the data fit the allometric model. (Perfect fit would be $r^2 = 1.0$.)

All relationships involving dry body weight were significantly different for intertidal and subtidal oysters.

The dry body weight/whole weight relationships for intertidal and subtidal oysters had significantly different b values, while the log a values were not significantly different. These findings mean that the growth relationships for intertidal and subtidal oysters varied with size; that is, the fitted lines are not parallel (Figure 2).

The shell weight/dry body weight relationships for intertidal and subtidal oysters had significantly different log a values, but similar b values. The subtidal ratio of shell weight/dry body weight is significantly higher than the similar intertidal relationship (Figure 2).

The dry body weight/soft body weight fitted

TABLE 1.—A comparison of the allometric coefficients for various morphological relationships for intertidal and subtidal oysters utilizing the equation $\log Y = \log a + b \log X$.

Relationship $\frac{Y}{X}$	Tidal level	Coefficients ± 95% C.I.		r^2	n
		log a	b		
dry body weight / whole weight	Inter	−1.687 ± 0.044	0.960 ± 0.032	0.92	298
	Sub	−1.539 ± 0.123	0.828 ± 0.081	0.77	107
shell weight / dry body weight	Inter	1.538 ± 0.026	0.966 ± 0.045	0.90	187
	Sub	1.652 ± 0.040	0.934 ± 0.097	0.77	107
dry body weight / soft body weight	Inter	−0.779 ± 0.016	0.970 ± 0.036	0.97	80
	Sub	−0.741 ± 0.020	0.931 ± 0.042	0.97	70
dry body weight / height	Inter	−2.383 ± 0.172	2.214 ± 0.197	0.87	80
	Sub	−1.889 ± 0.198	1.794 ± 0.232	0.78	70
dry body weight / length	Inter	−1.832 ± 0.133	2.694 ± 0.258	0.85	80
	Sub	−1.465 ± 0.223	1.987 ± 0.402	0.59	70
shell weight / whole weight	Inter	−0.142 ± 0.017	1.002 ± 0.012	0.99	187
	Sub	−0.109 ± 0.038	0.992 ± 0.025	0.98	107
shell weight / height	Inter	−0.803 ± 0.140	2.301 ± 0.148	0.92	80
	Sub	−0.572 ± 0.197	2.266 ± 0.230	0.85	70
shell weight / short axes width	Inter	−0.172 ± 0.142	2.682 ± 0.274	0.83	80
	Sub	−0.105 ± 0.228	2.635 ± 0.409	0.65	70
whole weight / height	Inter	−0.689 ± 0.127	2.329 ± 0.145	0.93	80
	Sub	−0.451 ± 0.194	2.262 ± 0.231	0.85	70
whole weight / length	Inter	−0.056 ± 0.139	2,726 ± 0.270	0.84	80
	Sub	−0.008 ± 0.224	2.645 ± 0.404	0.72	70
height / length	Inter	−0.090 ± 0.085	0.689 ± 0.097	0.85	80
	Sub	−0.047 ± 0.106	0.594 ± 0.124	0.57	70
whole body weight / soft body weight	Inter	1.013 ± 0.024	0.973 ± 0.052	0.95	80
	Sub	1.038 ± 0.044	1.072 ± 0.097	0.88	70
shell weight / soft body weight	Inter	0.088 ± 0.026	0.957 ± 0.055	0.94	80
	Sub	0.092 ± 0.048	1.069 ± 0.099	0.87	70
height / soft body weight	Inter	0.739 ± 0.014	0.391 ± 0.030	0.89	80
	Sub	0.681 ± 0.024	0.414 ± 0.052	0.79	70
length / soft body weight	Inter	0.407 ± 0.014	0.309 ± 0.030	0.85	80
	Sub	0.434 ± 0.026	0.290 ± 0.054	0.63	70

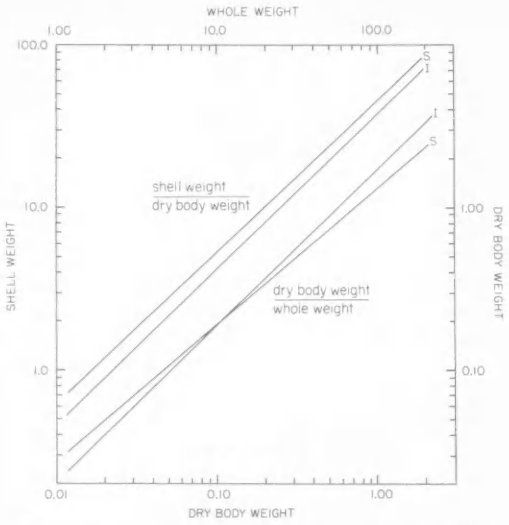

FIGURE 2.—The fitted allometric curves for the shell weight/dry body weight and dry body weight/whole weight relationships in intertidal (I) and subtidal (S) oysters.

equations had significantly different log a values (Figure 3). The ratio between dry body weight and soft body weight expresses the percent moisture in the tissues. The fitted expressions show that the percent moisture is almost constant with size since the fitted b values approach 1. The percent moisture is 83.4% in the intertidal oysters and 81.1% in the subtidal oysters.

The height/soft body weight relationships had significantly different log a values, but the b values were not significantly different (Figure 3).

The dry body weight/height relationships were significantly different in respect to their fitted log a values; the b values were not significantly different. Significantly different log a values, but similar b values indicate that the fitted curves are almost parallel (Figure 4).

The dry body weight/length relationships were the only fitted data with both significantly different log a and b values (Figure 4).

No significant differences were found between intertidal and subtidal oysters in the remaining relationships, and no significant differences were found between samples when each sample was calculated separately.

Data for subtidal oysters tended not to fit the allometric relationship as well as the intertidal oyster data. This tendency is indicated by the lower r^2 values for subtidal models, where $r^2 \times 100$ is an estimate of the percent variability of the data explained by a model. The lower r^2 values for subtidal oyster relationships may be partially attributed to the fact that fewer observations were made on this group of oysters.

DISCUSSION AND CONCLUSION

The quantitative relationships between the various parameters of weight and linear size for intertidal and subtidal oysters of different sizes have never been adequately described previously.

All significantly different relationships between intertidal and subtidal oysters involve dry body weight. Since a large proportion of the nutrients and energy available to the secondary consumers in the oyster food web is contained within the body of the oyster, this parameter is important in productivity studies. It is also important that the prediction of dry body weight

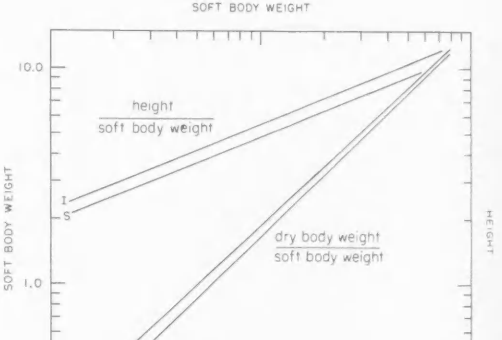

FIGURE 3.—The fitted allometric curves for the dry body weight/soft body weight and height/soft body weight relationships in intertidal (I) and subtidal (S) oysters.

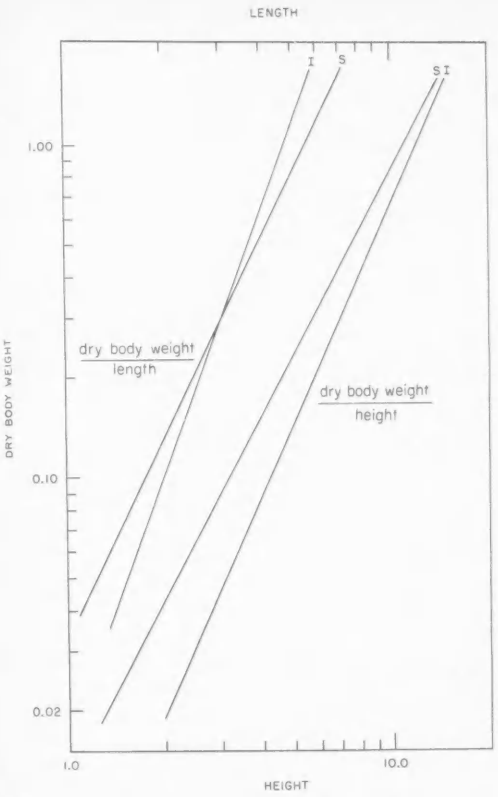

FIGURE 4.—The fitted allometric curves for the dry body weight/height and dry body weight/length relationships for intertidal (I) and subtidal (S) oysters.

from different measurements depends on significantly different models for the intertidal- and subtidal-zone oysters.

The shell weight/dry body weight ratio for *Crassostrea virginica* at North Inlet is significantly higher in subtidal oysters than in intertidal oysters. This observation supports the general observation of Galtsoff (1964) that the shells of intertidal oysters are usually thinner than those of subtidal oysters. The higher shell weight/dry body weight ratio for subtidal versus intertidal oysters is substantiated by the findings of Wilbur and Jodrey (1952), who showed that the amount of shell deposited by *C. virginica* was directly proportional to the time exposed to sea water. Rao (1953), observing a similar relationship between intertidal and subtidal *Mytilus edulis* and *M. californianus*, believed that the deposition of calcium by molluscs is directly dependent on the amount of time the animal is submerged. Baird and Drinnan (1957), finding a lower ratio of shell weight/dry body weight in subtidal *M. edulis* than in intertidal mussels of the same species, suggested that closed, exposed animals undergo anerobic metabolism which reduces body tissues more rapidly than chemical erosion of the shell. Lent (1957), discovering no differences in the shell weight/dry body weight ratio for the mussel *Modiolus demissus* from different tidal levels, attributed the result to the air-gaping phenomenon exhibited by *Modiolus*, which allows this organism to continue aerobic metabolism in both the submerged and exposed states. At present, it is doubtful if a general statement can be made that will resolve the different hypotheses. Thus, one might speculate that local environmental conditions such as tidal range, wave action, and water chemistry may be important in determining shell weight/dry body weight ratios.

In this study, the percentage water in the tissues, as calculated from the dry body weight/soft body weight relationship, falls within the reported range of 75-88% for *Crassostrea virginica* (Galtsoff, 1964). Intertidal oysters appear to retain a significantly higher proportion of their body water than subtidal oysters. The higher retention of water in intertidal oysters may result from some form of physiological adaptation to the intertidal environment, such as an increased ability to remain closed when they are exposed.

The relationships of dry body weight/whole body weight, dry body weight/height, and dry body weight/length are all different for intertidal and subtidal oysters, but there appears to be no obvious biological reason to explain these differences. It may simply be that any differences in dry body weight for intertidal and subtidal oysters are translated into differences in allometric relationships.

Galtsoff (1964) has noted that the condition index (dry body weight/volume of shell cavity

$\times$ 100) varies seasonally with the reproductive status of the adult oyster. The condition index was not measured in the present study, and no significant seasonal variations were found in any of the relationships.

It is interesting that in the present study no significant differences were found in the height/length relationships for intertidal and subtidal oysters. Glaser (1903), Orton (1936), Gunter (1938), and Galtsoff (1964) have noted differences in the long axis length/short axis width relationship for intertidal and subtidal oysters and have offered various reasons for these differences.

From the practical aspect, height appears to be the most useful parameter to predict other biomass parameters because of high coefficient of determination values in those relationships utilizing height and less time necessary to make each measurement.

In conclusion, quantitative relationships between various parameters of size can be different for oysters from intertidal or subtidal environments. These differences are important functionally in the biology of the organism and practically as predictive tools for ecological investigations.

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ACTIVITY AND FEEDING BEHAVIOR OF THE SUMMER FLOUNDER (*PARALICHTHYS DENTATUS*) UNDER CONTROLLED LABORATORY CONDITIONS

BORI L. OLLA, CAROL E. SAMET, AND ANNE L. STUDHOLME[1]

ABSTRACT

A group of five to six adult summer flounder, *Paralichthys dentatus* (Linnaeus), held under controlled laboratory conditions in a large, experimental, seawater tank, exhibited three general behavior patterns: (1) resting, (2) swimming, and (3) feeding. While resting on the sand surface, the fish maintained varying degrees of alertness, indicated by the position of the head and/or eye movements. Fish buried beneath the sand were considered to be in a lower state of responsiveness. The fish swam and glided at all levels in the water column or combined crawling and swimming to move along the sand. Activity measurements based on these swimming patterns indicated that the fish were primarily day-active. A range of feeding behaviors enabled the fish to capture prey equally well on the bottom or in the water column. The significance of these patterns and their relation to those of other flatfishes is discussed.

Until recent years, knowledge about the behavior of marine flatfishes has come mainly from the analyses of catches by fishing and research vessels to determine population structure, rates of recruitment, growth and mortality, migratory habits, and other aspects of life history from egg to adult stages. However, there are many questions that have been left unanswered, especially those concerning patterns of behavior that in many cases have a direct bearing on life habits.

One approach to answering questions on behavior is to observe the animal in the laboratory, under controlled conditions. Recent comprehensive laboratory studies on flatfishes have included work by Kruuk (1963) on *Solea vulgaris;* de Groot (1964) on *Pleuronectes platessa;* de Groot (1969) on *Solea solea, Limanda limanda, Pleuronectes platessa, P. flesus, Scophthalmus rhombus,* and *S. maximus;* and Verheijen and de Groot (1967) on *Pleuronectes platessa* and *P. flesus.* A most valuable paper by de Groot (1971) reviews the literature and discusses food, feeding behavior, and activity in flatfishes. These investigations have pointed to the diversity of their habits and the importance of comparative studies in understanding the interrelations between the various species.

In this work we have endeavored to further the understanding of some specific behaviors by studying, under controlled laboratory conditions, the activity cycles, feeding, and general swimming patterns of adult summer flounder, *Paralichthys dentatus* (Linnaeus), a species of major commercial and recreational importance.

MATERIALS AND METHODS

We observed five to six adult summer flounder, captured 16 to 48 km off the coast of Maryland. The fish ranged in length from 37.0 to 74.5 cm and in weight from 957.0 to 5,690.0 g.

We held the fish in an elliptical seawater aquarium, 10.6 × 4.5 × 3.0 m deep with a capacity of 121 kliter (Olla, Marchioni, and Katz, 1967). To provide a suitable bottom habitat for the fish, we added several layers of gravel, covered by an upper layer of 0.6 to 0.8 mm sand. Beneath the sand and gravel was a network of

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pipes designed to move filtered water through the layers to prevent contamination of the bottom. Water temperature in the tank ranged from 17.0° to 20.0°C. Salinity ranged from 23.0 to 26.0‰, oxygen from 6.5 to 7.7 mg/liter, and pH from 7.3 to 7.7.

Fluorescent lights mounted on two side walls above the aquarium were mechanically timed to approximate the natural daily photoperiod from morning to evening civil twilight. Since Verheijen and de Groot (1967) reported that high light intensities could inhibit normal activity in flatfish, we held the maximum daytime light intensity, as measured at the surface, at 3.5×10^2 mc. Preliminary measurements showed this level not to be inhibitory. An automated dimming system gradually raised and lowered light intensity during morning and evening civil twilight, avoiding sudden light changes that might startle the fish. A second lighting system, which switched on before the dimmer lights were extinguished, provided an indirect light of 2×10^{-1} mc as measured at the water surface (2.5×10^{-3} mc at 1 m below the surface) during the night period.

Throughout the course of the observations, at intervals of about 30 days, we fed the fish 1,100 to 4,400 g of live sand shrimp, *Crangon septemspinosa*, and grass shrimp, *Palaemonetes vulgaris*. The quantity of shrimp introduced each time insured a food supply which lasted for 30 days. According to Poole (1964) and Smith (1969), shrimp appear to be an important constituent of this species' natural diet.

Following 34 days of acclimation to the tank, we measured the activity of six fish over a 51-day period. At the end of this time, one fish died and our measurements were then based on five fish. Throughout the day and night, we made 5-min observations every hour 4 days each week of the number of fish swimming, feeding, or moving about on the bottom.

We found that 5 min was too brief to allow for extensive observations of the fish's behavior, so after establishing the daily cycle of activity, we lengthened these periods to 30 min every 3 hr 4 days each week. In conjunction with these extended observations, we periodically took motion pictures which allowed us to make a more detailed analysis of feeding and swimming. Gliding and swimming speeds were measured from these motion pictures as well as from stopwatch readings taken as the fish passed between two marks 335 cm apart.

RESULTS

We have classified the activity patterns of the fish into three general categories: (1) resting, either on the surface of the sand or beneath it, (2) swimming, and (3) feeding. Within these three categories, we have described the various aspects of each behavior in an attempt to provide a clearer picture of the fish's habits.

RESTING

The summer flounder exhibited three basic resting positions: (1) lying flat on the sand; (2) lying on the sand with the head raised (as much as 7.5 cm), supported by the body musculature and the anterior portions of the dorsal and anal fins braced vertically into the sand; and (3) buried beneath varying amounts of sand.

In the first resting position, while flat on the sand, the eye turrets were either retracted or extended. When extended, the eyes either remained relatively fixed or moved up to 6 to 8 times per min. When the head was raised, as in the second resting position, eye movements were generally more frequent, ranging from 10 to 30 times per min, reflecting a higher degree of responsiveness. This "head-up" posture was generally characteristic of an animal at a higher level of activeness than fish lying flat.

Fish in either resting position occasionally "yawned." The head was elevated, the mouth opened, and the opercula extended. Yawning occurred either as a single event or up to 16 times in rapid succession. As yawning was repeated, the gape of the mouth increased and the head rose progressively farther off the sand. During the 30-min observation periods, we recorded the events preceding and following 33 yawns, i.e., separate occurrences, whether comprised of a single yawn or a number of successive yawning movements. Of these, 24 preceded an immediate

change in activity; i.e., 17 times yawning preceded swimming from a resting position, 2 times it preceded burying, and 5 times, a change in position. In seven instances, 5 to 10 min elapsed, before the fish proceeded to bury (2 times), swim (4 times), or change position (once). The remaining two instances occurred as the fish settled on the sand after swimming. It appeared from these findings that yawning generally was associated with changes in activity. This is similar to the increased activity following yawning in the yellowtail demoiselle, *Microspathodon chrysurus*, (Rasa, 1971).

The buried position was characteristic of fish in a state of low responsiveness, similar to that shown by fish lying flat on the surface of the sand. The eyes seldom rotated and a buried fish did not respond to prey that moved or settled directly within its line of vision. Burying began with an upthrust of either head or tail which continued as a beating of the head and tail alternately against the sand, from 5 to 10 times, until the fish was partially or completely covered. This took 1.5 to 3.0 sec.

The events leading to burying were apparently nonspecific. For instance, after swimming, some flounder would settle on the sand and immediately bury. Other flounder resting on the sand for as long as 20 min would, for no reason apparent to the observer, bury. We also found that, as described below, burying might occur as a secondary response when the fish were subjected to an intense or sudden stimulus.

SWIMMING

Swimming movements could begin from any resting position and could be classified into three categories. In one category, fish swam in the water column, at any depth from surface to bottom, at speeds ranging from 19.0 to 58.0 cm/sec. As a fish swam, the head moved up and down while the body musculature expanded and contracted, the whole process viewed as a series of rhythmic undulations. The caudal fin exerted most of the momentum for forward movement; the left pectoral (the eyed side) and to a lesser extent, the right pectoral, acted as rudders. To counteract their natural negative buoyancy, and hence the tendency to sink, the fish were continually in motion, swimming at one level or swimming upward.

A second type of swimming combined active propulsion and gliding. The fish would swim upward in the water column (Figure 1A and B) and then, by positioning the head downward and

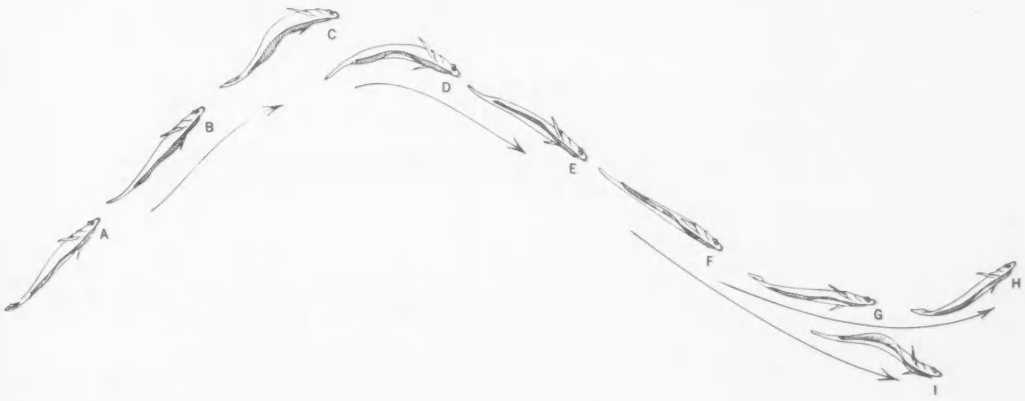

FIGURE 1.—Swimming and gliding behavior. A swimming fish (A, B) flexes from head to midsection (C) to begin a glide. As the head drops (D) and the body flattens (E), the fish glides downward and forward (F, G). At any depth, the fish can either resume swimming (H) or brake its forward glide (I).

flattening the body, would glide downward and forward (Figure 1C-H). The angle and rate of descent were controlled by the position of the head and body relative to the bottom as well as by the position of the dorsal, anal, and caudal fins. By raising the pectoral fins and posterior portions of the dorsal and anal fins, while simultaneously lowering the anterior portions of the dorsal and anal fins and arching the body, the fish could brake its forward motion in midwater (Figure 1I), either to change swimming direction or to approach a potential prey. Gliding was an effective means of covering distances while in the water column. Starting at a height of 1.8 m from the bottom, a fish could glide 4.5 to 6.5 m at speeds ranging from 34.0 to 64.0 cm/sec.

A third type of swimming combined swimming within 5 to 15 cm of the sand and crawling ("shambling" as described by Kruuk, 1963; and Verheijen and de Groot, 1967). This was most often observed when the fish were actively seeking prey. Shambling speeds ranged from 32.0 to 48.0 cm/sec.

ACTIVITY CYCLE

Based on hourly counts of the number of fish swimming in the water column or moving along the sand, we found the flounder to be primarily day-active (Figure 2A-H) although the light level at night was apparently sufficient to permit swimming and feeding.

Throughout the course of our observations, there was an overall decrease in activity occurring first at night (Figure 2B) and then during the day (Figure 2E-H). During this time, the photoperiod was changing, approximating the natural seasonal daylength. While changing photoperiod may act as an assignable cause for the decline in the fish's activity, observations included only a small part of the natural seasonal photoperiod cycle, too brief a time to permit a definitive statement as to its influence on activity.

FEEDING

The fish could feed with as much facility on the bottom as in the water column. Bottom

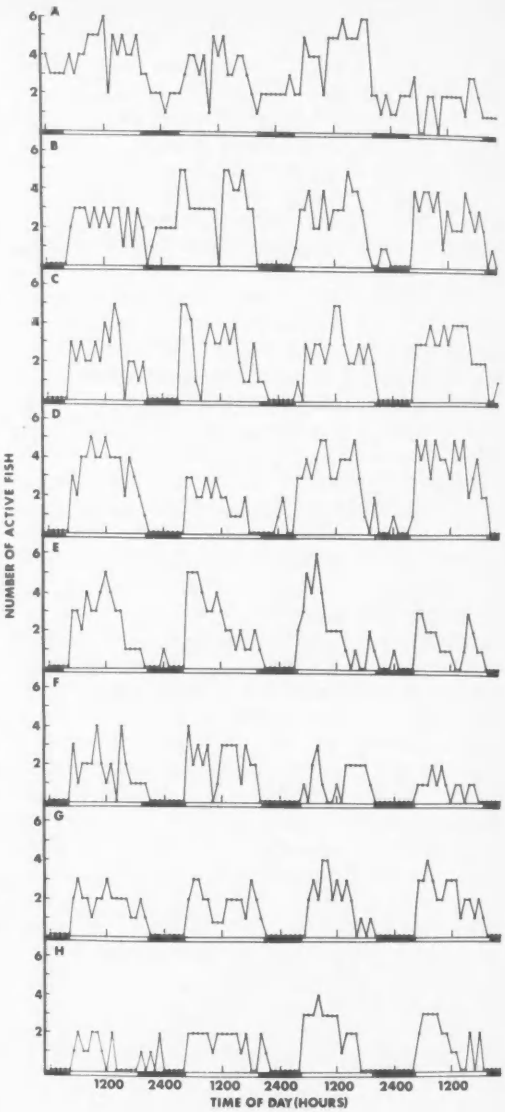

FIGURE 2.—Number of fish swimming in the water column or moving along the sand. Counts were taken at hourly intervals throughout the day and night under the following average photoperiods: (A) 16.3 hr; (B) 16.4 hr; (C) 16.4 hr; (D) 16.3 hr; (E) 16.2 hr; (F) 16.0 hr; (G) 15.9 hr; (H) 15.8 hr.

feeding was always preceded by active prey search. In most instances, a flounder, after selecting a potential prey, would rest on the sand with the head slightly raised. Then, while visually fixing on a shrimp, the fish would begin to stalk, crawling on the sand towards the prey. This crawling was viewed as waves of cephalocaudal movements of the dorsal and anal fins (Figure 3A-D). When a fish was within striking distance (5-10 cm), the head was angled downward or lay flat on the sand. The midsection of the body was arched, supported by the caudal fin and by portions of the edges of the dorsal and anal fins braced into the sand (Figure 4A). As the caudal fin beat downward (Figure 4B), the fish sprang forward, mouth agape and opercula spread, striking and ingesting the shrimp (Figure 4C). Speed during the strike was about 40 to 50 cm/sec. After ingestion, there was continued mouth movement, apparently part of the pharyngeo-esophageal activity necessary for swallowing.

Fish that were resting on the bottom, with the head either up or down, would not strike at shrimp even though prey were well within striking distance. Feeding was always preceded by active search, although these fish were seemingly well-adapted for a "lying-in-wait" method of prey capture.

Fish swimming 50 to 70 cm above the bottom could also capture shrimp from the sand. As a swimming fish (Figure 5A) visually fixed on a single shrimp, speed abruptly decreased (Figure 5B). While the flounder was still moving forward, it would tilt towards the sand at a 30° to 45° angle. At this point, with the prey about

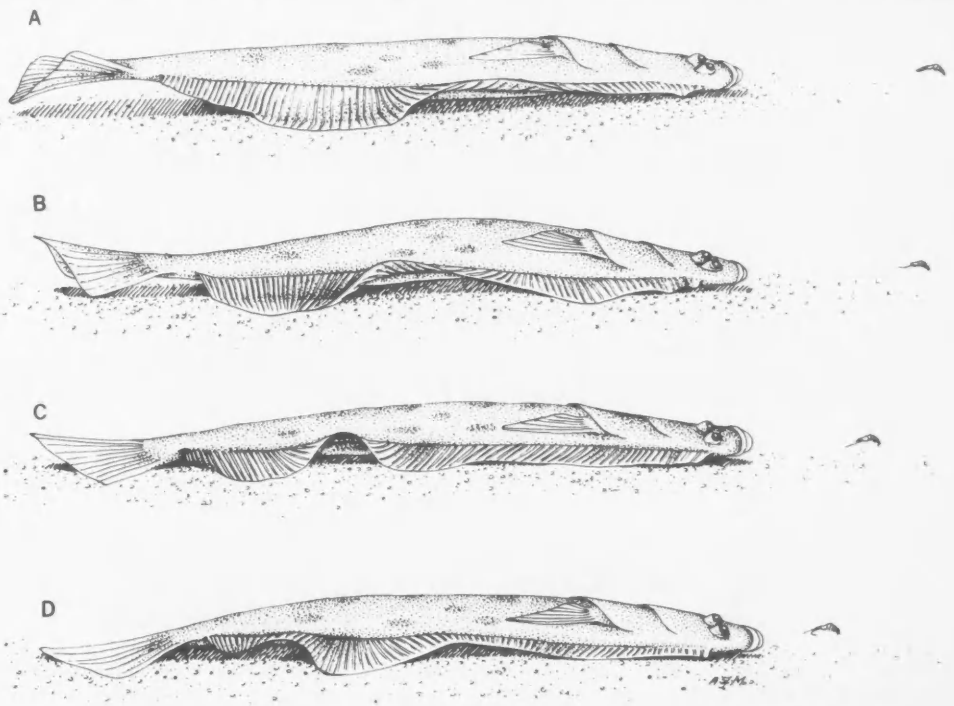

FIGURE 3.—Stalking behavior. The fish visually fixes on a shrimp and crawls slowly forward on the dorsal and anal fins (A-D).

20 cm away, its forward motion almost ceased. Then, when within 3 to 5 cm of the prey (Figure 5C), the fish beat downward with the caudal fin and with mouth agape and opercula spread, moved forward and downward. As the fish ingested the shrimp, it would usually make contact with the bottom with its snout, then glance off the sand, and move slightly forward and upward (Figure 5D). The fish would then resume swimming or settle on the sand.

The basic elements of prey selection and visual fixation were essentially the same whether the fish were feeding in the water column or on the bottom. While the flounder were actively swimming or gliding toward shrimp, they would approach and decrease speed by raising posterior portions of the dorsal and anal fins and arching the body into a partially flexed position. Then, with a rapid caudal flexion, the fish would capture and ingest the shrimp. As was the case with bottom feeding, after capturing a prey, a fish would either continue active search or settle on the sand.

The searching, stalking, active eye movements, and visual fixation on specific prey all indicated that vision was a primary sense used in feeding during the day. We observed feeding at night, and while it appeared to us that the role of vision was similar to that in the day, we could not preclude the possibility of other senses playing more dominant roles.

At times the flounder would approach a prey, as if to begin stalking or a capture, but would then turn away. We considered this type of behavior to be a feeding intention movement. For example, a flounder would swim toward shrimp on or near the bottom, assume a prestrike posture, visually fix on a shrimp, and open and close

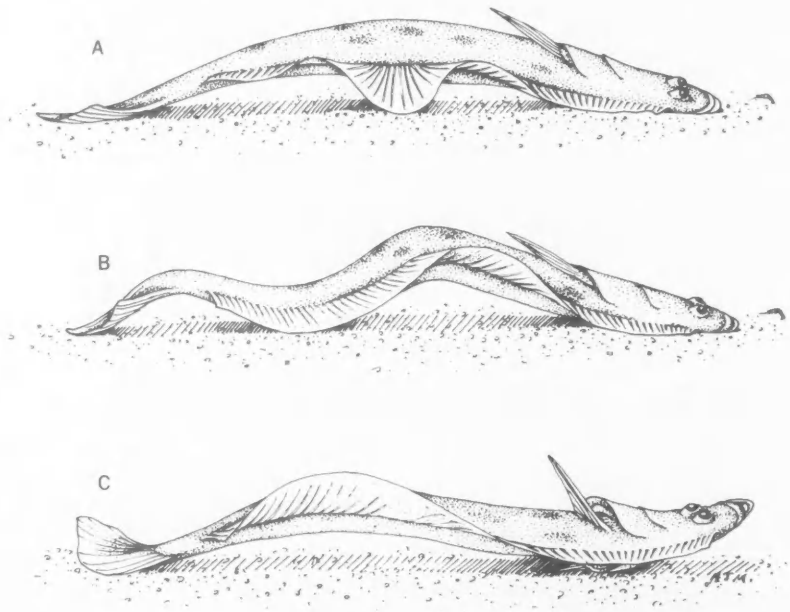

FIGURE 4.—Prey capture following stalking. The fish assumes a position prior to striking. The body is slightly raised off the sand and the eyes are visually fixed on the prey (A). As the strike begins, the caudal fin beats downward (B), thrusting the fish forward for the capture (C).

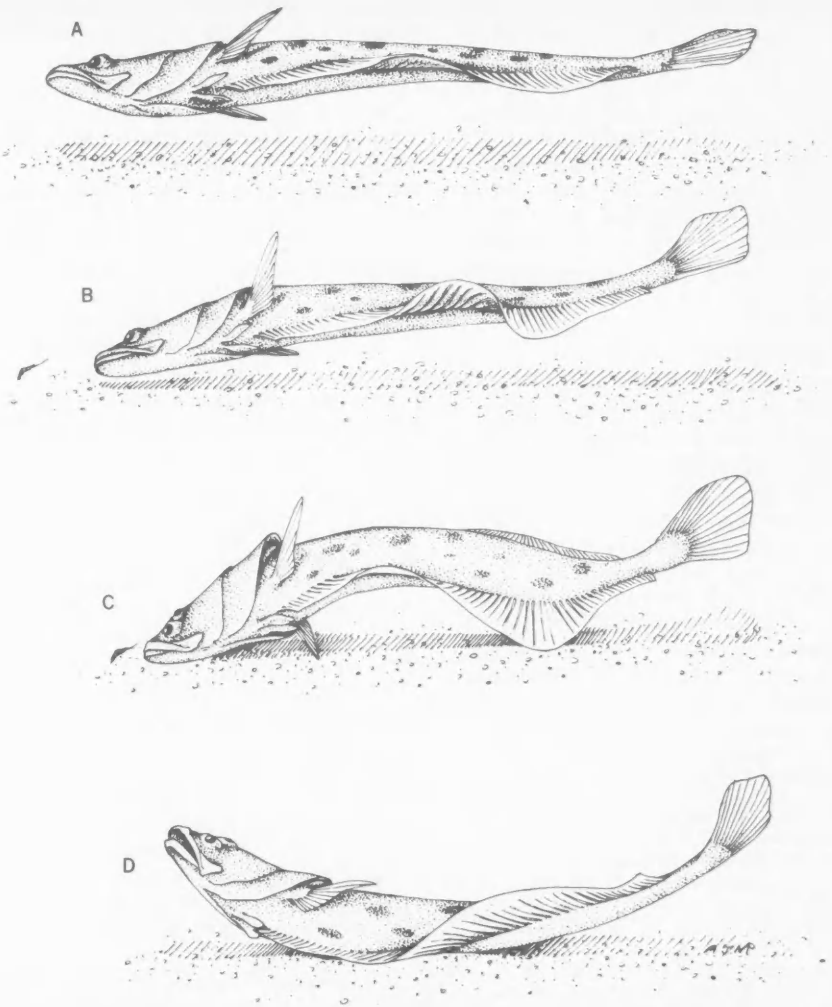

FIGURE 5.—Bottom feeding by a swimming fish. A swimming fish (A) visually fixes on a shrimp on the bottom, partially brakes its forward motion (B), and tilts toward the sand. As the caudal fin beats downward, the mouth opens, the opercula spread, and the fish moves ahead to ingest the shrimp (C, D).

its mouth several times. Then, without lunging or striking at the prey, the fish would swim away after a few seconds.

We found feeding intention movements to occur after the fish had been feeding. For instance, in one case, after we had introduced 1,100 g of shrimp into the tank (29 days after the last feeding of 4,400 g of shrimp), the fish began to feed within 3 min. One fish, after eating 13 shrimp within a 22-min period, exhibited

an intention movement 3 min later. Then four more shrimp were ingested during the next 20 min, followed 2 min later by two additional intention movements. A second fish ingested 15 shrimp within 35 min and 2 min later made an intention movement. A third fish, after ingesting 16 shrimp in 26 min, made an intention movement 1 min later, then fed immediately on one shrimp, and 2 min later exhibited an intention movement. These movements may have been related to a reduction of feeding motivation as a result of satiation.

FRIGHT RESPONSE

We observed what was apparently a "fright" response to a sudden stimulus under two different circumstances. In one case, there was a malfunction of the dimmer lights which caused the sudden onset of the daylight lights. A swimming fish immediately dropped to the bottom where it remained resting on the sand surface. In another case, an observer above the tank waved his arms as a fish moved about near the water surface. The fish immediately dropped to the sand, darkened, and assumed a rigid posture. The head and caudal fin lay flat, but the dorsal and anal fins were arched in two places along their length. The fish remained in this posture for about 45 sec during which it slowly lowered first the anterior, then the posterior sections of the dorsal and anal fins until they were flat. The flounder then swam about 2 m away and buried. In both instances, the initial response of the fish to a fright stimulus was to drop to the bottom and remain motionless. Burying occurred as a secondary response.

DISCUSSION

Previous descriptions of the habits of summer flounder have characterized them as primarily bottom-oriented, except for occasional sorties to the surface in pursuit of prey (Bigelow and Schroeder, 1953:267-270). Furthermore, this species has been described as being relatively immobile, except while feeding or during the normal migratory period (Ginsberg, 1952). In our laboratory observations, while the fish frequently searched for and captured prey on the sand and also remained quiescent on the bottom for long periods, they would also frequently use the water column for swimming, prey search, and feeding. In fact, during one part of our study, the fish swam and glided for extended periods throughout all levels of the tank, seldom resting in any one position.

The gliding behavior we observed could play an important role for the animal in the sea. After reaching the surface, the fish could travel considerable distances with little or no active swimming movements, using natural negative buoyancy and body shape to full advantage. Positioning of the fins and body would control forward speed and distance traveled. Although there might have been a sacrifice in speed, the gliding would represent a saving in energy as compared with that required to swim the same distance. Gliding would also enable the animal to search for and capture prey in the water column more efficiently, since it could approach a prey with less gross movement than would occur during active swimming. This might lessen the chance of eliciting escape responses from the prey due to visual or mechanical stimuli. Another adaptive advantage of gliding in food search might be related to the fact that the head was steady, thus making it easier to keep the prey in the visual field.

Although the summer flounder were primarily day-active, we observed burying, feeding, shambling, and swimming both day and night. Similar to the summer flounder, turbot (*Scophthalmus maximus*) swim and are active on the bottom primarily during the day, although both activities may occur at night to a lesser degree (de Groot, 1971). Verheijen and de Groot (1967) and de Groot (1971) established that plaice (*Pleuronectes platessa*) and flounder (*P. flesus*) showed a nocturnal pattern of swimming in the upper water column, while during the day they would shamble or swim over the bottom searching for food. Kruuk (1963) and de Groot (1971) found that the sole (*Solea vulgaris*) also had a nocturnal period of high activity under both natural and artificial light.

The method of burying in the summer flounder is similar to Kruuk's (1963) description of "digging-in" in the sole. In the sole as well as the

winter flounder, *Pseudopleuronectes americanus*, (McCracken, 1963) and starry flounder, *Platichthys stellatus*, (Orcutt, 1950), burying could be induced as a direct response to a sudden disturbance, such as a change in light intensity or moving object. In the summer flounder, apparently the primary response to a fright stimulus is to assume a stationary and sometimes rigid posture on the bottom. This is followed by burying as essentially a secondary response.

There are numerous descriptions of the sensory mechanisms utilized by different groups of flatfishes during feeding (see de Groot, 1971, for review). Since summer flounder are primarily day-active, it was not surprising that vision played a primary role in prey selection and capture. According to de Groot (1971), this is apparently characteristic of Bothidae including brill (*Scophthalmus rhombus*) and turbot, which he designated as visual day-feeders, largely dependent on visual stimuli for locating prey. Despite the fact that the summer flounder would also be categorized in this manner, we did observe feeding at night. Although the light level of 2.5×10^{-3} mc (as measured at 1 m below the surface) fell slightly below the 10^{0}-10^{-2} mc level cited by Blaxter (1970) as the range in which most visual feeders cease active feeding, it was possible that vision was still being utilized.

The summer flounder, winter flounder, (Olla, Wicklund, and Wilk, 1969), and lemon sole, *Microstomus kitt*, (Steven, 1930) may rest on the bottom with head up while actively moving their eyes. In the latter two species, the fish may be searching for food and will lunge forward from this position to strike at and capture prey. While we considered summer flounder in this position to be alert and responsive, it was also apparent that this was not necessarily indicative of a prefeeding strike. Although Ginsberg (1952) stated that summer flounder lie in wait for passing prey, we found that the fish, even in this alert "head-up" posture, never lunged from a resting position at a prey, even though it was only a few centimeters away, but always preceded prey capture by active searching.

While we do not understand the role yawning plays in the behavior of the summer flounder, we did find evidence that it was associated with changes in activity. Rasa (1971) found that yawning in the yellowtail demoiselle was associated with an increased excitement level. She postulated that the strong muscle contraction that occurs during yawning could serve to increase the blood flow and oxygen to the body musculature and thereby facilitate the onset of the animal's activity. It may also be conceivable that yawning movements may act to flush sand or debris from the gill areas, one function suggested for yawning in Pacific bonito, *Sarda chiliensis*, (Magnuson and Prescott, 1966).

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THE EFFECTS OF TEMPERATURE AND PHOTOPERIOD ON REPRODUCTIVE CYCLING IN THE ESTUARINE GOBIID FISH, *GILLICHTHYS MIRABILIS*

VICTOR L. DE VLAMING[1]

ABSTRACT

Investigations were undertaken at several different times during the year to examine the effects of various photoperiods and constant-temperature regimes on reproductive function in the longjaw goby, *Gillichthys mirabilis*, with the intent of evaluating the influence of these factors in regulation of the annual sexual cycle. Testicular regression occurs at any time during the year when fish are exposed to constant temperature of 24°C and above, independent of photoperiod. Similar results were obtained with female fish, but 22°C is the thermal threshold. It is concluded that the gonadal regression observed in the Alviso population of this species during the summer months is a consequence of increasing temperature. At high temperatures, the transformation of spermatogonia to spermatocytes is blocked, and in females vitellogenesis is inhibited. The degree of gonadal regression is temperature-dependent. Gonadal recrudescence is dependent on low temperatures (10°-20°C) and will not occur if fish are exposed to high temperatures (24°C or above) regardless of photoperiod. At low temperatures, short photoperiods accelerate recrudescence. Between January and June spermatogenesis and oogenesis are maintained at temperatures between 10° and 21°C; long photoperiods are more effective in this respect, but not essential. Termination of the reproductive season in this species is not endogenously timed. Regression is not "obligatory" since gonadal involution does not occur at the "normal" time if fish are exposed to temperatures of 20°C or below.

The survival of any species in a seasonally changing environment is dependent on the development of mechanisms that permit it to adjust physiological functions to changes in the environment. Studies of reproductive timing and how the environment influences this timing are of importance in understanding the ecology of any species.

Compared with the wealth of information available on the systematics, ethology, and physiology of fishes, there is little knowledge concerning how external factors regulate their reproduction. Some investigations have been undertaken to elucidate the role of environmental factors in regulating the reproductive cycles of various teleosts. The relationship of environmental factors to the reproductive cycles of gobies has not received experimental consideration. Moreover, experimental work with the environmental control of teleost reproductive cycles has been confined to fewer than 20 species representing only 8 families.

Photoperiod and temperature are presumed to be the most important factors (i.e., the most studied) influencing the neuroendocrine centers that control gonadotropin secretion in teleosts (de Vlaming, 1972a). The experimental conditions employed in a majority of the previous studies, however, are diverse and the results contradictory. In fact, most of the experimental work was too poorly controlled and too brief in duration to allow proper assessment of the role of the environment in synchronizing fish reproduction (de Vlaming, 1972a).

The subject of the present study is the longjaw goby, *Gillichthys mirabilis*. It is distributed

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from central California south to Magdalena Bay, Baja California, and the Gulf of California south to Mulegé on the west coast, and south to Agiabampo Bay on the east coast (Barlow, 1963). The typical habitat of this species is the intertidal region of coastal sloughs. Barlow (1961, 1963) discussed the systematics and some aspects of the ecology of *G. mirabilis*. The population of *Gillichthys* used in these studies occurs in the Alviso salt ponds located at the southern end of San Francisco Bay, Calif. Carpelan (1957) described seasonal changes in the hydrobiology of these ponds.

De Vlaming (1972b) described the reproductive cycle of *G. mirabilis* and suggested that seasonal temperature changes may be involved in regulating sexual cycling in this species. The spawning period is protracted, extending from December to June. Gonadal regression occurs in July; the gonads remain regressed during August and September. Gonadal recrudescence begins in late September, reaching completion by early December.

The aim of the present study was to determine the effects of various light and constant temperature regimes on gonadal function in *G. mirabilis*, with the hope of evaluating the influence of these factors in regulation of the annual sexual cycle. The phenological data on reproductive cycling in this species presented by de Vlaming (1972b) was used as a basis for these studies. Some of the previous studies with teleosts have shown that the effect of the environmental synchronizer(s) varies with the stage of gonadal maturity. Consequently, the effects of photoperiod and constant temperature treatments were examined during different phases of the gonadal cycle.

MATERIALS AND METHODS

Samples of *G. mirabilis* were captured in the Alviso habitat at several different times during the year and thus in different phases of gametogenesis. Since males were more abundant in these samples, a greater number of experiments were conducted with this sex. Several fish from each sample were sacrificed, and the gonads examined at the time of capture; these fish served as a reference for the experiments that followed. In the following discussion the fish sacrificed from the samples from nature will be referred to as initial controls. In many of the experiments, samples of fish from the natural habitat were collected and sacrificed upon termination of the experiment; these fish will be referred to as terminal controls. To facilitate quantification of gonadal response, animals of approximately equal size were utilized in these experiments.

Experimental fish were maintained in 56- (no more than 10 fish per tank) or 132-liter (no more than 18 fish per tank) tanks. Recirculating filtered seawater was used in all of these experiments. The bottom of each tank was covered with fine gravel. The experimental tanks were housed in constant temperature rooms (± 1.5°C). Temperatures selected for these experiments are within the range normally experienced by this species during the year.

Various photoperiods were also employed in these experiments. Light was provided by 20-w warm-white fluorescent bulbs suspended above the tanks. Salinity was maintained at a constant 35 ‰, and pH between 8.0 and 9.5 (these pH's are consistent with those experienced by the fish in the Alviso ponds). The fish in these experiments were provided with a varied diet consisting of brine shrimp, chopped fish, boiled egg white, and beef kidney and liver; all fish ate voraciously.

Upon termination of each experiment, the weight and standard length of each fish were recorded. Gonads were weighed and prepared for histological examination in the same manner as previously reported (de Vlaming, 1972b). Gravimetric data are expressed in absolute weights since it was shown (de Vlaming, 1972b) that gonadal weight is independent of body weight (and length) in the size range used. Spermatogenesis and oogenesis were divided into six and five recognizable phases (Tables 1 and 2) to facilitate quantitative evaluation of gametogenetic activity.

Statistical comparisons of gonadal weights between experimental groups were made by using the Mann-Whitney *U* test (Siegel, 1956, p. 184-193). This nonparametric test is suitable for small sample sizes and can be used to determine

TABLE 1.—Criteria used for histologically staging testes of *Gillichthys mirabilis*.

Stage	Histological characteristics of testes
0	"Regressing testis." Seminiferous lobules characterized by large numbers of pyknotic nests of degenerating cells (spermatozoa, spermatids, and spermatocytes); phagocytes observed free within the lobules.
1	"Quiescent testis." Seminiferous lobules small in diameter. Germinal epithelium consists of only spermatogonia. Lumen of the lobules contain only few residual spermatozoa, and the sperm duct is collapsed.
2	"Mitotic phase." Same as Stage 1, with the exception that mitotic figures are observed in the spermatogonia.
3	"Meiotic phase or active spermatogenesis." Testicular lobules larger than in Stages 1 and 2; germinal epithelium consists of spermatogonia, spermatocytes, and spermatids.
4	"Prespawning testis." Seminiferous lobules large and distended with sperm. Germinal epithelium consists of relatively few spermatogonia.
5	"Postspawning testis." Seminiferous lobules small and contain relatively few sperm; sperm duct expanded and containing residual sperm.

TABLE 2.—Criteria used for histologically staging ovaries of *Gillichthys mirabilis*.

Stage	Histological characteristics of ovaries
I	"Regressing ovary." Atretic follicles predominate in the ovary. Only nonyolky oocytes and oogonia present.
II	"Quiescent phase or phase of oogonial proliferation." Ovary characterized by nonyolky oocytes with a basophilic cytoplasm, and a diameter of less than 75 μ. Granulosa not fully organized around the developing oocytes.
III	"Phase of active vitellogenesis." Ovary characterized by developing yolky oocytes whose diameter is between 75 μ and 640 μ. Granulosa fully organized around the oocytes.
IV	"Prespawning condition." Ovary characterized by oocytes whose diameter is in excess of 640 μ. Yolk vesicles abundant.
V	"Postspawning condition." The ovary is wine-red in color; the tunica albuginea thick, highly vascularized, and folded. Postovulatory follicles predominate in the ovary. The stroma of the ovary appears disorganized, yet highly vascularized.

whether two independent groups have been drawn from the same population.

RESULTS

EFFECTS OF CONSTANT TEMPERATURE AND PHOTOPERIOD ON FISH WITH REGRESSING GONADS

To examine the influence of low and high temperature treatments at different photoperiods on gonadal recrudescence, fish with regressing testes (Stage 0) and ovaries (Stage I) were collected in July 1967. Fish were exposed to 13°C, at a short (8L/16D) or long (15L/9D) photoperiod, or to 27°C at a short photoperiod (8L/16D).

The effects of these treatments on testicular and ovarian weights are summarized in Figure 1. The testes (Stage 0) and ovaries (Stage I) of all of the initial controls were regressing. After 57 days, testicular and ovarian weights increased significantly ($P < 0.01$) at both photoperiods at 13°C, and were also significantly greater ($P < 0.01$) than those of fish from nature sacrificed at the same time. Ovarian weights of females exposed to 8L/16D at 13°C were significantly greater ($P < 0.01$) than those of fish exposed to 15L/9D at the same temperature.

Testes of all fish at 13°C were in the meiotic phase of spermatogenesis (Stage 3) whereas those of all fish in the September sample from nature were only in Stage 2 (mitotic proliferation phase). The ovaries of all fish at 13°C were in phases of vitellogenesis (Stage III); the oocytes of fish at 8L/16D were, however, in a

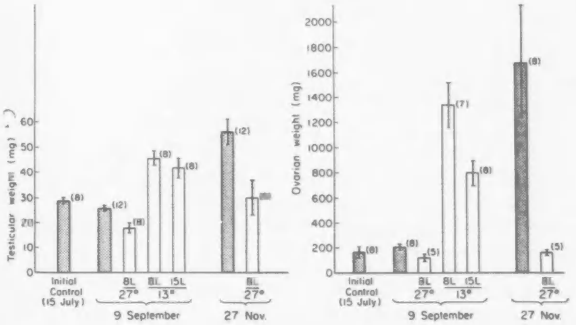

FIGURE 1.—Effect of 13°C at a long (15L/9D) photoperiod and 13° and 27°C at a short (8L/16D) photoperiod on testicular and ovarian weight in *Gillichthys mirabilis*. Mean gonadal weight is illustrated by histograms; the mean is bracketed by one standard error. Shaded histograms represent gonadal weight of samples collected in nature; open histograms, experimental groups. Light (hours per 24 hr), temperature, and dates on which fish were sacrificed are recorded below the histograms. Sample sizes are indicated atop each histogram.

later stage of vitellogenesis. The ovaries of all fish in the September nature sample were in the quiescent phase (Stage II).

After 57 days at 27°C, testicular weights were significantly lower ($P < 0.05$) than those of the initial July controls. The testes of all fish were in the quiescent phase (Stage 1), even after 134 days. In contrast, the testes of all fish in the November sample from nature were in Stage 3.

Ovarian weights of fish exposed to 27°C (both the September and November samples) did not differ significantly from those of the initial July controls, but they were significantly lower ($P < 0.01$) than ovarian weights of both 13°C groups. The ovaries of the 27°C treated fish revealed only resting oocytes (Stage II). However, the ovaries of fish in the November sample from nature were in Stage III, IV, or V.

Thus, low temperatures promote gonadal recrudescence in *Gillichthys*, independent of photoperiod. Short photoperiods may accelerate the rate of gonadal recrudescence at low temperatures. A short photoperiod, however, failed to initiate gonadal recrudescence at high temperature. High temperatures act by blocking vitellogenesis and the transformation of spermatogonia to spermatocytes.

The influence of constant temperature and photoperiod on testicular recrudence was examined again in July 1968, using 13° or 20°C, with a short (8L/16D) and a long (15L/9D) photoperiod. A fifth group was exposed to 24°C at a long photoperiod (15L/9D). Each group was sampled after 45, 70, and 120 days (Figures 2 and 3).

In the initial July controls testes were regressing (Stage 0). At 24°C testicular weights remained low throughout the experiment; in September and November testicular weights at this temperature were significantly lower ($P < 0.05$) than those of the initial July controls. Moreover, at 24°C testes remained in the regression or quiescent phase (Stage 0 or 1) throughout the experiment (Figure 3).

At 20°C testicular weights remained essentially the same as in the initial July controls

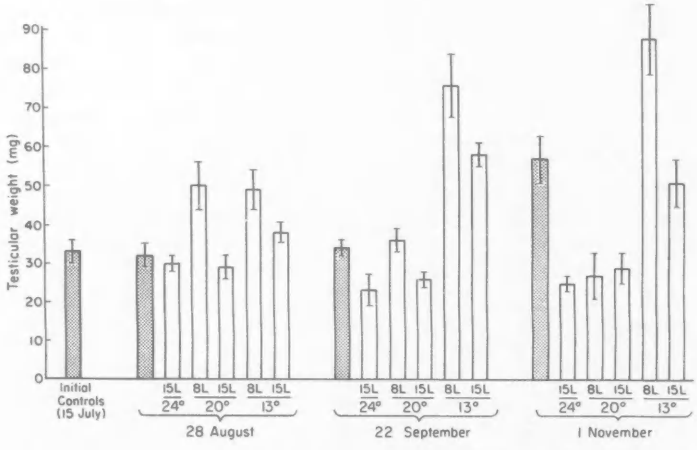

FIGURE 2.—Effect of 24°, 20°, and 13°C treatments at short (8L/16D) and long (15L/9D) photoperiods on testicular weight in *Gillichthys mirabilis*. Mean testicular weight is represented by histograms; the mean is bracketed by one standard error. Shaded histograms represent testicular weight of samples collected in nature; open histograms, experimental groups. Light (hours given per 24 hr), temperature, and dates on which fish were sacrificed are recorded below the histograms. For sample sizes, see Figure 3.

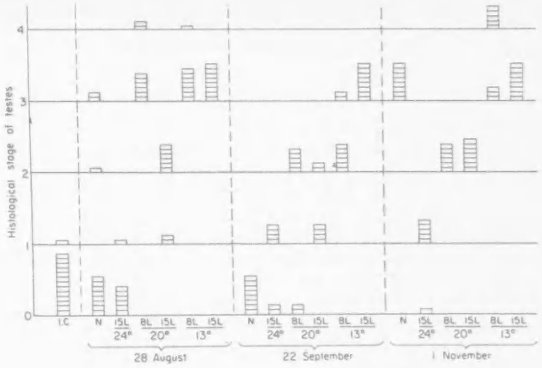

FIGURE 3.—Effect of 24°, 20°, and 13°C treatments at short (8L/16D) and long (15L/9D) photoperiods on testicular histology in *Gillichthys mirabilis*. I.C. refers to initial controls (15 July) and N_1 to samples from natural population. Each box represents the testicular condition of one fish.

with one exception. Testicular weights of the 20°C group at 8L/16D sacrificed in August were significantly greater ($P < 0.05$) than those of the July controls. With the exception of this same group, active spermatogenesis was not initiated in fish exposed to 20°C. Mitotic proliferation of spermatogonia was, however, stimulated by this treatment. In contrast, active spermatogenesis was initiated by August at 13°C, regardless of photoperiod. Active spermatogenesis was not initiated in the natural population until after 22 September. Testicular weights of both groups at 13°C sacrificed in September were significantly greater ($P < 0.01$) than those of the initial July controls and those of the September sample from nature. Some photoperiod effect was evident at 13°C since testicular weights at 8L/16D were significantly higher ($P < 0.05$) than those of the 15L/9D group by September. By November, the testes of a majority of the fish in the 13°C-8L/16D group were in the prespawning condition (Stage 4) whereas the testes of all fish in the 13°C-15L/9D group were in Stage 3; testicular weights of these two groups were also significantly different ($P < 0.01$).

These data indicate that 24°C inhibits testicular recrudescence by blocking the transformation of spermatogonia to spermatocytes and also retards mitoses in the spermatogonia. Low temperatures promote testicular recrudescence; the rate of recrudescence at a low laboratory temperature was faster than in the natural population. At low temperatures, short photoperiods accelerate testicular recrudescence. With the exception of the one sample at 20°C-8L/16D sacrificed in August, 20°C stimulates little or no testicular recrudescence, only mitotic proliferation of spermatogonia.

EFFECTS OF CONSTANT TEMPERATURES AND PHOTOPERIOD ON FISH IN STAGES OF ACTIVE GAMETOGENESIS (MAY)

Responses of fish in phases of active gametogenesis (in May) were examined by exposing two groups of fish for 67 days to 13°C, at a short (8L/16D) and a long (15L/9D) photoperiod, and 27°C at a long photoperiod (15L/9D). The effects of these treatments on gonadal weights are summarized in Figure 4.

At the beginning of treatment, testes and ovaries were in Stages 3 and III, respectively. In the July sample from nature, sacrificed with the experimentals, ovarian (Stage I) and testicular (Stage 0) regression was occurring. Testes and ovaries of fish at 27°C regressed as in nature; in both sexes gonad weights were significantly lower ($P < 0.01$) than initial levels.

In both groups at 13°C spermatogenetic activity remained at the initial levels and the testes did not show the regression seen in nature or at 27°C. Ovarian weights in the 13°C group at a long photoperiod were significantly lower ($P < 0.05$) than those of the initial May sample

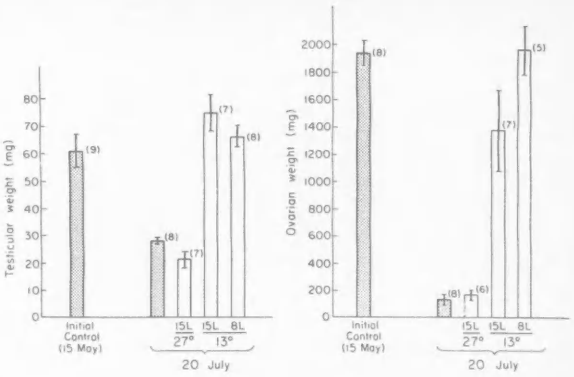

FIGURE 4.—Effect of 27° and 13°C treatments at short (8L/16D) and long (15L/9D) photoperiods on testicular and ovarian weight in *Gillichthys mirabilis*. Mean gonadal weight is represented by histograms; the mean is bracketed by one standard error. Shaded histograms represent gonadal weight of samples collected in nature; open histograms, experimental groups. Light (hours given per 24 hr), temperature, and dates on which fish were sacrificed are recorded below the histograms. Sample sizes are indicated atop each histogram.

and those of the 13°C group at a short photoperiod. Ovaries in both 13°C groups were, however, in active vitellogenesis (Stage III). These results could indicate a photoperiod influence in vitellogenesis. But one must observe caution in interpreting these data since this difference in ovarian condition may simply be a problem of beginning experiments with fish in various stages of oogenesis. Data presented by de Vlaming (1972b) revealed the nonsynchrony of gametogenesis in this species (i.e., fish in different stages of gonadal development were common in monthly samples between November and June).

High temperatures apparently cause testicular and ovarian regression in spring, at least when the photoperiod is long, whereas low temperatures prevent gonadal regression and are required for spermatogenesis and vitellogenesis.

EFFECTS OF CONSTANT TFMPERATURES AND PHOTOPERIOD ON FISH IN STAGES OF ACTIVE SPERMATOGENESIS (JANUARY)

In the previous experiment the influence of temperature and photoperiod was examined during the spawning season in spring. Whether fish respond similarly in winter (near the onset of the spawning season) is also of interest, so in January 1968 fish were exposed to 27°, 20°, and 13°C, at a short (8L/16D) or a long (15L/9D) photoperiod for 30-39 days. The influence of these treatments on testicular weight and histology is presented in Figures 5 and 6, respectively.

Testes of the initial January controls were in Stages 3, 4, or 5. As observed in May, testes regressed rapidly at 27°C; testes weights were significantly less ($P < 0.01$) than those of the January controls and February sample from nature. Histological examination confirmed that regression had occurred (testes in Stage 1). No photoperiod effect was seen at 27°C.

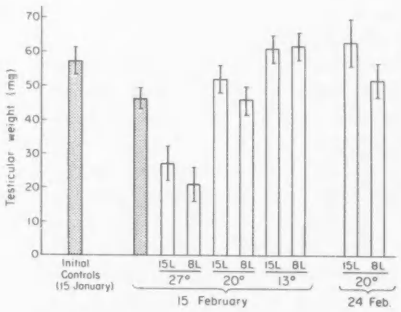

FIGURE 5.—Effect of 27°, 20°, and 13°C treatments at short (8L/16D) and long (15L/9D) photoperiods on testicular weight in *Gillichthys mirabilis*. Mean testicular weight is represented by histograms; the mean is bracketed by one standard error. Shaded histograms represent testicular weight of samples collected in nature; open histograms, experimental groups. Light (hours given per 24 hr), temperature, and dates on which fish were sacrificed are recorded below the histograms. For example sizes, see Figure 6.

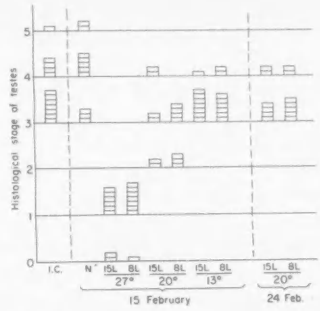

FIGURE 6.—Effect of 27°, 20°, and 13°C treatments at short (8L/16D) and long (15L/9D) photoperiods on testicular histology in *Gillichthys mirabilis*. I.C. refers to initial controls (15 January) and N, to sample from natural population. Each box represents the testicular condition of one fish.

Testicular weights in the 20°C groups remained at approximately the initial level. Both groups at 20°C had significantly heavier ($P < 0.01$) testes than those of the 27°C groups. The testes of all fish at 20°C advanced to Stages 3 or 4 by 24 February, and there was no clear photoperiod effect. Testicular weights of the 13°C groups did not differ significantly from the initial January controls but were significantly greater than those of the 20°C group at a short photoperiod ($P < 0.05$) and those of the 27°C groups ($P < 0.01$). Spermatogenic condition of the testes in the 13°C groups was essentially the same as in the January controls and February sample from nature (Figure 6).

The results of this experiment indicate that spermatogenesis is maintained at 13°C and 20°C (independent of photoperiod) but that this process may occur at a slower rate at 20°C than at 13°C. This difference in effect of these two temperatures must be accepted with some reservation because the variability of gonadal development in the initial controls could introduce a degree of bias into the results. Regardless of photoperiod, testicular regression occurred at 27°C.

EFFECTS OF HIGH TEMPERATURES ON GONADAL FUNCTION IN DIFFERENT SEASONS

Experiments using high temperatures were initiated at different times during the year to determine whether there is a seasonal variation in gonadal susceptibility to such treatment. The conditions employed and results obtained in these experiments are summarized in Table 3.

Experiments I and II indicate that 24°C is a sufficiently high temperature to initiate testicular regression within a relatively short period. With either a long (15L/9D) or a short (8L/16D) photoperiod (Experiment III), 25°C stimulates the completion of testicular regression within 21 days; testes of these fish were in the quiescent phase (Stage 1). A temperature

TABLE 3.—Effect of various high temperature and photoperiod treatments on testicular weight in *Gillichthys mirabilis*.

Experiment numbers	Date	Length of treatment (Days)	Temperature (°C)	Photoperiod (L/D)	Testicular weight (mg) ($\bar{x} \pm SE$)		
					Initial controls	After treatment	(n)
I	May 69	21	24	12/12	79.1 ± 5.2	58.1 ± 3.1**	(7)
II	Feb. 70	15	24	14/10	79.1 ± 9.5	34.4 ± 2.5**	(9)
III	Feb. 68	21	25	15/9	43.7 ± 3.4	25.0 ± 1.6*	(7)
	Feb. 68	21	25	8/16	43.7 ± 3.4	23.2 ± 4.8*	(7)
IV	July 70	30	27	10/14	22.3 ± 7.8	18.1 ± 1.4	(8)
V	Nov. 69	14	27	12/12	64.8 ± 8.8	30.0 ± 2.7**	(8)
VI	Apr. 70	8	27	12/12	97.8 ± 7.4	46.7 ± 3.9**	(10)
VII	July 68	41	24	12/12	33.1 ± 3.2	28.9 ± 2.2	(7)
	July 68	41	28	12/12	33.1 ± 3.2	18.1 ± 2.2*	(8)
VIII	June 68	21	27	12/12	52.2 ± 3.9	26.2 ± 2.7**	(7)
	June 68	21	30	12/12	52.2 ± 3.9	14.8 ± 3.1**	(8)
IX	Apr. 68	8	28	12/12	62.2 ± 5.4	40.1 ± 4.2**	(7)
	Apr. 68	14	28	12/12	62.2 ± 5.4	24.3 ± 1.8**	(9)
	Apr. 68	8	32	12/12	62.2 ± 5.4	15.6 ± 2.8**	(8)

*Significantly less ($P < 0.05$) than initial controls.
**Significantly less ($P < 0.01$) than initial controls.

of 25°C does not, however, block mitotic proliferation of spermatogonia.

Experiment IV (Table 3) indicates that 27°C blocks the initiation of testicular recrudescence. Testicular regression is initiated within 14 days at 27°C (Experiment V); the testes of all fish were in the regression phase (Stage 0). Moreover, Experiment VI suggests that testicular regression is initiated within 8 days at 27°C; the testes of all fish were regressing (Stage 0).

When initial controls are undergoing testicular regression, 28°C stimulates a more rapid completion of regression than does 24°C (Experiment VII). This is evident since the testes of a majority of the fish at 28°C were in the quiescent phase (Stage 1) whereas those of the 24°C group were in Stage 0. A 30°C temperature (Experiment VIII) causes a more complete testicular regression than does a 24°C temperature (i.e., testicular weights of the 30°C group were significantly lower ($P < 0.01$) than those of the 27°C group). Both of these treatments caused the completion of testicular regression within 21 days; the testes of a majority of fish in both groups were in the quiescent phase (Stage 1). Similarly, 32°C stimulates a more rapid and more complete testicular regression than 28°C (Experiment IX); testicular weights after 8 days were significantly lower ($P < 0.01$) in the 32°C group than those of the 28°C group. Testes of all fish at both temperatures were regressing (Stage 0). After 14 days at 28°C, testicular weights were still significantly higher ($P < 0.05$) than testicular weights after 8 days at 32°C (Experiment IX).

With the exception of the experiments in which the initial controls were fish with regressing gonads, all high temperature treatments summarized in Table 3 caused a significant decrease in testicular weights. These data indicate that the rate of testicular regression and the degree of testicular regression are temperature dependent. These data also indicate that under laboratory conditions testicular involution is initiated relatively soon after exposure to high temperatures and that regression can be completed rapidly in this species.

Experiments similar to those discussed above were conducted with female *Gillichthys* (Table 4). Beginning with fish in active vitellogenesis (Stage III), 25°C initiates ovarian regression (Stage I) within 21 days, independent of photoperiod (Experiment 1). Ovarian weights in the two photoperiod groups were not significantly different. Beginning with fish having regressing ovaries (Experiment 2), 27°C caused the completion of ovarian regression. Experiment 3 suggests that ovarian regression is complete within 21 days at 30°C; the ovaries of a majority of the initial controls were in phases of active vitellogenesis (Stage III), whereas following treatment, the ovaries of all fish were in the quiescent phase (Stage II).

Experiment 4 (Table 4) indicates that 32°C stimulates a more rapid rate of ovarian regression than does 28°C; ovarian weights of the 32° and 28°C groups were significantly different ($P < 0.01$) after 8 days of treatment. Ovarian regression was occurring in all fish. After 14 days at 28°C, further ovarian regression occurred, but involution had still not been completed.

Therefore, temperatures between 25° and 32°C initiate ovarian regression within a relatively short time; all high temperature treatments caused a significant decrease in ovarian weights. Apparently the completion of ovarian regression is temperature dependent.

EFFECTS OF 21°-22°C AND PHOTOPERIOD TREATMENT ON GONADAL FUNCTION

The previous experiments suggest that gonadal regression occurs at 24°C but not at 20°C. To define more precisely the thermal threshold for gonadal involution, the effects of 21°-22°C treatments were examined in April, May, September, and November. The conditions employed and results obtained in these experiments are summarized in Table 5.

Beginning in April with fish in active spermatogenesis or in the prespawning condition (Stage 3 or 4), there was no change in testes after 17-day treatment at 22°C (15L/9D). However, after 30-day treatment at 22°C and a short photoperiod (10L/14D), there was a significant decrease ($P < 0.01$) in both ovarian and testicular weights (Experiment 11—Table 5). Testes

TABLE 4.—Effect of various high temperature and photoperiod treatments on ovarian weight in *Gillichthys mirabilis*.

Experiment number	Length of treatment (Days)	Temperature (°C)	Photoperiod	Weight of ovaries (mg) ($\bar{x} \pm$ SE)		
				Initial controls	After treatment	(n)
1	21	25	15L/9D	1,744 ± 422	381 ± 81**	(7)
	21	25	8L/16D	1,744 ± 422	480 ± 108**	(8)
2	30	27	10L/14D	484 ± 98	188 ± 4*	(8)
3	21	30	12L/12D	1,638 ± 219	190 ± 76**	(8)
4	14	28	12L/12D	3,042 ± 305	654 ± 181**	(6)
	8	28	12L/12D	3,042 ± 305	1,790 ± 423**	(6)
	8	32	12L/12D	3,042 ± 305	871 ± 312**	(8)

*Significantly less ($P < 0.05$) than initial controls.
**Significantly less ($P < 0.01$) than initial controls.

of the May controls were in active spermatogenesis (Stage 3) or in the prespawning conditions (Stage 4); ovaries of the May controls were in active vitellogenesis (Stage III). The testes of six of the eight fish at the short photoperiod, however, were regressing (Stage 0); ovaries in this group were regressing (Stage I) or in the quiescent phase (Stage II).

In contrast to the effects of short photoperiod at 22°C, a long photoperiod (in May) did not initiate testicular regression. Although testicular weights in this group were significantly less ($P < 0.05$) than those of the initial May controls, the testes of all fish were in active spermatogenesis (Stage 3). Ovarian weights of fish at a long photoperiod were also significantly lower ($P < 0.01$) than those of the initial May controls; ovarian regression (Stage I) was occurring in all fish.

Beginning in September, 26-day exposure to a short photoperiod (10L/14D) at 21°C stimulated a significant increase ($P < 0.05$) in ovarian and testicular weights when compared to gonadal weights in the initial controls (Experiment 12—Table 5). In contrast, neither ovarian nor testicular weights in the long photoperiod group were significantly altered. The testes of the September controls were in Stage 2, and the ovaries of this group were in early stages of vitellogenesis (Stage III). After short photoperiod treatment, the gonads of all fish were in the meiotic phase of spermatogenesis (Stage 3) or vitellogenesis (Stage III); the long photoperiod, however, did not stimulate spermatogenesis (testes in this group were in Stage 1) and caused ovarian regression (Stage I).

Beginning in November (Experiment 13), testicular weights were maintained at the initial level for 21 days at 22°C and a short photoperiod (10L/14D); testes of the initial controls and the experimental fish were in Stage 3 or 4. A long photoperiod at 22°C, however, caused the initiation of testicular regression (Stage 0); testicular weights in this group were significantly

TABLE 5.—Effect of 21° and 22°C treatments on testicular and ovarian weight in *Gillichthys mirabilis*.

Experiment number	Beginning date	Length of treatment (Days)	Temperature (°C)	Photoperiod		Gonadal weight (mg) ($\bar{x} \pm$ SE)		
						Initial controls	After treatment	(n)
10	April	17	22	15L/9D	males:	97.8 ± 7.4	99.2 ± 8.8	(10)
11	May	30	22	10L/14D	males:	88.4 ± 7.1	43.3 ± 2.3**	(8)
					females:	1,263 ± 186	681 ± 242**	(7)
11	May	30	22	15L/9D	males:	88.4 ± 7.1	70.6 ± 6.1*	(8)
					females:	1,283 ± 186	691 ± 216**	(6)
12	September	26	21	10L/14D	males:	42.8 ± 7.4	61.5 ± 7.8*	(8)
					females:	233 ± 39	364 ± 44*	(6)
12	September	26	21	15L/9D	males:	42.8 ± 7.4	36.0 ± 4.2	(7)
					females:	233 ± 39	166 ± 21	(6)
13	November	21	22	15L/9D	males:	68.5 ± 9.7	46.9 ± 6.3**	(10)
13	November	21	22	10L/14D	males:	68.5 ± 9.7	79.5 ± 5.1	(8)

*Significantly different ($P < 0.05$) from initial controls.
**Significantly different ($P < 0.01$) from initial controls.

lower ($P < 0.01$) than those of the initial November controls.

In spring spermatogenesis occurs at 22°C only if the photoperiod is long and in autumn only if the photoperiod is short. This temperature causes ovarian regression regardless of photoperiod, suggesting that females may be more sensitive to temperature than males. Similarly, 21°C will promote the initiation of testicular and ovarian recrudescence only if photoperiod is short. Apparently then, the effects of photoperiod at these temperatures are seasonally variable.

EFFECTS OF PHOTOPERIOD AT 20°C ON FISH WITH REGRESSING OR QUIESCENT GONADS

Experiments reported above showed that gonadal recrudescence will not occur at 20°C if treatment is initiated in July but that gametogenesis is maintained at this temperature at other times during the year. Thus, the influence of 36-day 20°C treatment at various photoperiods on gonadal recrudescence was examined in August 1968 (Figure 7). The gonads of the initial August controls were in Stages 0 and 1. Neither testicular nor ovarian weights in any of the experimental groups varied significantly from gonadal weights in the initial August controls, and there were no significant differences in gonadal weights among the experimental groups. Differences in gonadal histology were, nonetheless, evident. Testes of all fish collected from nature in August and September were in the regression phase (Stage 0). In all photoperiod groups testicular regression was complete, and spermatogonial proliferation (Stage 2) or spermatogenesis (Stage 3) was occurring. The testes of 4 of 10 fish at a 15L/9D photoperiod, however, were in the quiescent phase (Stage 1). A majority of ovaries from fish collected from nature in August and September were in the quiescent phase (Stage II). In each experimental group, the ovaries of some fish were in the early phases of vitellogenesis (Stage III); with the exception of one fish, vitellogenesis was initiated in all females at 15L/9D.

These results indicate that gonadal recrudescence is initiated at 20°C if treatment is begun

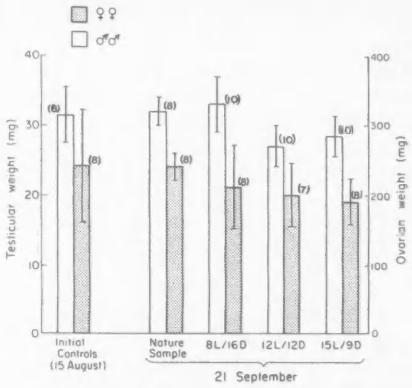

FIGURE 7.—Effect of 36-day 20°C treatment at various photoperiods on ovarian and testicular weight in *Gillichthys mirabilis*. Shaded histograms illustrate mean ovarian weights; open histograms illustrate mean testicular weights; the means are bracketed by one standard error. Photoperiod treatments are given below the histograms. Sample sizes are indicated atop each histogram.

in August. Recrudescence was initiated after 36 days in all photoperiod groups, but a long photoperiod (15L/9D) was most effective in females and least effective in males.

EFFECTS OF 16°C TREATMENT ON GONADAL FUNCTION

Gonadal recrudescence does not normally occur if *Gillichthys* is exposed to 20°C in July. To examine whether recrudescence could be initiated in July at a slightly lower temperature, the effect of 16°C treatment was determined. Before examining the effects of this temperature treatment on recrudescence, an experiment was conducted in January to be certain that gametogenesis could be maintained at this temperature. The ovaries of the initial January controls (Table 6) were in Stage III, IV, or V; the testes of fish in this sample were in Stage 4 or 5. Neither testicular nor ovarian weights were significantly altered by this 90-day treatment, nor was there an evident change in gonadal activity as judged by histological examination.

The testes and ovaries of the initial controls of the July experiment (Table 6) were regres-

sing (Stages 0 and I). Following 80-day treatment at 16°C, ovarian and testicular weights were significantly greater ($P < 0.01$) than those of the initial controls. Testes of the experimental fish were in Stage 3 or 5. Ovaries of fish in the 16°C group were in Stage II or III.

The results of these experiments indicate that spermatogenesis and vitellogenesis are maintained at 16°C. In fish with regressing gonads (collected in July), 16°C treatment initiates spermatogenesis and oogenesis.

EFFECTS OF LONG PHOTOPERIOD TREATMENT (15°C) ON FISH WITH REGRESSING TESTES

In July 1969 an experiment was initiated to determine whether a long photoperiod could block recrudescence at an "intermediate" temperature. All of the initial controls were undergoing testicular regression (Stage 0); the mean (± SE) testicular weight (mg) in this sample was 32.3 ± 2.2. Fish were exposed to 15°C for 30 days at a 15L/9D photoperiod. At the termination of the experiment a sample of fish was taken from nature; the mean testicular weight (± SE) in this group was 20.7 ± 3.2, and the testes of these fish were regressing (Stage 0). Testicular weights ($\bar{x} \pm SE = 58.3 \pm 7.3$) of the 15°C group were significantly greater ($P < 0.01$) than those of the initial July controls and the September sample from nature. The testes of nine fish in the 15°C group were in Stage 3, and those of three were in Stage 4. These data suggest that 15°C treatment initiates testicular recrudescence, even when the photoperiod is long.

TABLE 6.—Effect of 16°C treatment (12L/12D) on testicular and ovarian weight in *Gillichthys mirabilis*.

Beginning date	Length treatment (Days)	Sex	Gonadal weight (mg) ($\bar{x}$ ± SE) Initial controls	After treatment	(n)
January	90	Males	71.6 ± 4.9	66.7 ± 4.0	(10)
		Females	1,321 ± 295	1,136 ± 238	(11)
July	80	Males	32.3 ± 2.2	54.5 ± 4.1**	(10)
		Females	256 ± 23	438 ± 34**	(10)

**Significantly greater ($P < 0.01$) than initial controls.

EFFECTS OF 12° AND 20°C TREATMENT ON FISH IN STAGES OF ACTIVE GAMETOGENESIS

Data presented above suggest that gametogenesis may be maintained more effectively at 13°C than at 20°C. Beginning in March 1968, fish were exposed to 20° and 12°C for 21 days to examine this possibility (Table 7). The ovaries of the initial March controls were in phases of active vitellogenesis (Stage III) or the prespawning or postspawning condition (Stage IV or V); the testes of this group were in Stage 3.

TABLE 7.—Effect of 21-day 12° and 20°C treatments on ovarian and testicular weights in *Gillichthys mirabilis*.

Experimental group	Gonadal weight (mg) ($\bar{x}$ ± SE) Males	(n)	Females	(n)
Initial controls (March)	59.3 ± 6.1	(11)	1,038 ± 198	(11)
12°C treatment	74.7 ± 6.3*	(10)	1,428 ± 106	(8)
20°C treatment	58.8 ± 5.7	(7)	1,375 ± 123	(8)
Terminal controls (April)	62.2 ± 5.4	(8)	3,043 ± 297	(18)

*Significantly greater ($P < 0.05$) than initial controls.

Ovarian weights in the two experimental groups did not differ significantly from those of the initial March controls, but they were significantly less ($P < 0.01$) than ovarian weights of the sample taken from nature at the time of sacrifice (April). Ovaries of the 20° and 12°C groups were in Stage III or IV; the ovaries of a majority of the April sample from nature were in Stage IV.

Testicular weights in the 20°C group were not significantly altered by treatment, but those of the 12°C group were significantly greater ($P < 0.05$) than the testicular weights of the initial March controls. The testes of fish in the 12°C group were in Stage 3 or 4; however, the testes of four of seven fish at 20°C were in Stage 2 and the remainder in Stage 3.

These data indicate that at a 12L/12D photoperiod, vitellogenesis and spermatogenesis will occur at both 12° and 20°C but that the lower temperature is more effective. Neither of these treatments, however, was as effective in promoting vitellogenesis as the factors acting on the natural population.

INHIBITION OF TESTICULAR REGRESSION BY LOW TEMPERATURE

An experiment was initiated in June 1968 to resolve whether low temperature treatment in combination with a short photoperiod could prevent gonadal regression at the "normal" time (early July). The testes of the beginning controls were in the prespawning or postspawning conditions (Stages 4 or 5). Fish were exposed to 10° or 20°C at a 10L/14D photoperiod for 21 days. The testes of fish collected from nature at the time of sacrifice (July) of the experimentals were regressing (Stage 0). Testicular weights in the 10°C group ($\bar{x} \pm SE = 60.7 \pm 4.1$) and the 20°C group ($61.0 \pm 6.2$) did not vary significantly from those (52.2 ± 3.9) in the initial June controls, but those of both groups were significantly greater ($P < 0.01$) than testicular weights of the July sample from nature (32.1 ± 3.1). The testes of 10 fish exposed to 10°C and 6 fish to 20°C were in active spermatogenesis (Stage 3), and 4 in each group were in the prespawning condition (Stage 4). Thus, testicular regression does not occur at the normal time when fish are exposed to temperatures between 10° and 20°C.

COMPARATIVE EFFECTS OF 10° AND 18°C TREATMENT ON GONADAL RECRUDESCENCE

To determine whether there is a differential effect of 10° and 18°C on gonadal recrudescence, a 21-day experiment was initiated in August 1970 with fish having regressing or quiescent gonads (Stages 0 and 1). The effects of these treatments on gonadal weight are presented in Table 8.

TABLE 8.—Effect of 21-day 10° and 18°C treatments (13L/11D) on ovarian and testicular weights in *Gillichthys mirabilis*.

Experimental group	Gonadal weight (mg) ($\bar{x} \pm SE$)			
	Males	(n)	Females	(n)
Initial controls (August)	32.5 ± 2.1	(10)	280 ± 18	(8)
10°C treatment	42.6 ± 4.4*	(8)	339 ± 48	(8)
18°C treatment	41.7 ± 7.3*	(8)	386 ± 33*	(8)

*Significantly greater ($P < 0.05$) than initial controls.

A significant increase ($P < 0.05$) in testicular weights occurred at both 10° and 18°C; testicular weights in the two groups were not significantly different. Spermatogenesis was initiated in all fish in both experimental groups. Ovarian weights in fish exposed to 18°C were significantly greater ($P < 0.05$) than those of the initial August controls; however, ovarian weights in the 10°C group were not significantly different than those of the initial controls or those of the 18°C group. Nonetheless, the ovaries of all fish in both experimental groups were in early phases of vitellogenesis (Stage III).

These data indicate that there is little or no difference in the rate of initiation of gonadal recrudescence at 10° and 18°C. The possibility exists, however, that following the initiation of recrudescence, the rate of testicular and ovarian growth could be different at the two temperatures.

DISCUSSION

In previous work (Barlow and de Vlaming, 1972; de Vlaming, 1972b), the gonadal cycle of *Gillichthys* was observed to be closely correlated with seasonal changes in several environmental variables. Gonadal regression occurs as daylength begins to shorten and temperature reaches a seasonal maximum. The initiation of gonadal recrudescence coincides with the decline in temperature and the continued decrease in daylength. A majority of the spawning in this species occurs when daylength and temperature are increasing. The data presented here suggest that temperature may be important with regard to reproductive cycling, photoperiod acting only to modify the responses to temperature.

GONADAL REGRESSION

In these laboratory experiments, constant temperatures of 24°C and above cause testicular and ovarian regression at any time of the year regardless of photoperiod (i.e., photoperiod does not seem to have an influence on gonadal regression). As temperature is increased above 24°C, shorter treatment periods are required to attain the ovarian and testicular quiescent phases.

High temperatures bring about ovarian regression by inhibiting vitellogenesis and causing atresia of all yolky oocytes. In males, high temperatures apparently increase the rate of meiotic divisions and the process of spermiogenesis; this is apparent because the testes of fish sacrificed soon after the initiation of high temperature treatment are characterized by large numbers of secondary spermatocytes and spermatids. Fish sacrificed after longer treatments at high temperatures, however, are characterized by testes with only primary spermatogonia, suggesting that high temperatures inhibit the transformation of spermatogonia into primary spermatocytes. High temperatures also cause the "flaking off" of cysts of spermatocytes from the germinal epithelium into the lumen of the testicular lobules. Moreover, pyknotic degeneration of spermatocytes, spermatids, and spermatozoa occurs at high temperatures, followed by phagocytosis of cellular debris. Mitotic proliferation of spermatogonia is inhibited above 25°C, but treatment at 27°C for 15 days does not inactivate the sperm remaining in the testes. Weisel (1948) showed that the spermatozoa of *Gillichthys* remain alive in vitro for 2 weeks at 2°-4°C, but at 24°-26°C they are immobile in 33 hr.

In *Gillichthys* the termination of the reproductive season is apparently not endogenously timed. Regression is not "obligatory" since low temperature treatments (regardless of photoperiod) prevented gonadal involution at the "normal" time (July). These studies imply that the reproductive cycle of this species is primarily under exogenous regulation. A similar situation has been reported in the cyprinodontid, *Epiplatys bifasciatus* which occurs in the Zio River and Lagoon of Lomé of the Republic of Togo, Africa (Loiselle, 1969). *Gillichthys* is thus apparently a potentially continuous breeder but has a reproductive cycle imposed upon it by the increased temperatures of summer. Although little information is available on the causes of termination of reproductive cycles, differences are evident. For example, Baggerman (1957) suggested that since none of the experimental conditions she tested could maintain continuous breeding in *Gasterosteus aculeatus*, termination of the cycle is endogenously controlled. The rate of postspermatogonial regression is also accelerated by warm temperatures, and low temperatures retard the rate of sexual regression in *Fundulus heteroclitus* (Lofts, Pickford, and Atz, 1968).

GONADAL RECRUDESCENCE

In *Gillichthys* gonadal recrudescence does not occur at constant temperatures of 24°C or above, regardless of photoperiod. Long-term experiments indicate that gonadal recrudescence is not initiated in males or females after nearly 4 months at high temperatures (comparable to summer temperatures). High temperatures also retard the early phases or intermediate phases of gametogenesis in *Fundulus heteroclitus* (Burger, 1939), *Phoxinus laevis* (Bullough, 1939), female *Apeltes quadracus* (Merriman and Schedl, 1941), *Enneacanthus obesus* (Harrington, 1956), female *Fundulus confluentus* (Harrington, 1959), *Couesius plumbeus* (Ahsan, 1966), and *Cymatogaster aggregata* (Wiebe, 1968).

Experiments, begun in winter and spring with the longjaw goby in phases of active gametogenesis, indicate that gonadal activity is maintained at 20°C over a wide range of photoperiods; long photoperiods may be more effective in this regard, but more experiments are needed to prove conclusively the influence of photoperiod. Beginning in July with fish having regressing testes, mitotic proliferation of spermatogonia was stimulated, especially with a short photoperiod, but complete recrudescence did not occur at 20°C. However, beginning in August with fish having regressing testes, recrudescence did occur at 20°C; a short photoperiod was more effective in this respect. Beginning in September, testicular and ovarian recrudescence is initiated at 21°C, but only with a short photoperiod. The rate of spermatogenesis was, however, extremely low at these temperatures. Thus, a shift in gonadal responsiveness to 20°C apparently occurs between July and August. The experiment beginning in July was continued for 3 months without the initiation of spermatogenesis whereas the experiment beginning in August was terminated after a much shorter time. The

adaptive significance of the "refractoriness" to 20°C in July may be to prevent "premature" initiation of spermatogenesis should temperatures decrease somewhat during the regression phase.

Although the data presented here are by no means conclusive, they suggest that photoperiod has a variable effect at 20°C. Long photoperiods may be more effective in maintaining spermatogenesis whereas short photoperiods seem to promote a faster rate of recrudescence at 20°C. Moreover, active spermatogenesis is maintained at 22°C only with a long photoperiod. Differences are evident between the sexes since vitellogenesis does not occur at this temperature regardless of photoperiod. Since a majority of spawning in *Gillichthys* occurs when daylength is increasing and recrudescence occurs when daylength is decreasing, the variation in the effects of photoperiod seen here seem reasonable.

That 20°C is not as effective as lower temperatures in maintaining gametogenesis or promoting gonadal recrudescence is consistent with the phenological and climatic data presented by de Vlaming (1972b). Average daily temperatures are below 20°C from early October to mid-June; it is during this period that most of the gonadal activity occurs in this species.

Complete gonadal recrudescence in both male and female *Gillichthys* occurred at 12° and 13°C, suggesting that the decreasing temperatures in autumn are primarily responsible for regulating this process. Constant low temperature treatment promoted a faster rate of recrudescence than occurred in the natural population. Diurnal increases in temperature in the natural habitat during autumn may account for the slower rate of gonadal recrudescence. Short photoperiods augmented the rate of recrudescence at low temperatures in both males and females. Thus, the decreasing photoperiod in autumn probably facilitates, but is not essential for, the effects of decreasing environmental temperatures in promoting gonadal recrudescence.

With a 12L/12D photoperiod, gonadal recrudescence was initiated within 21 days at 10° and 18°C. This suggests that gonadal response in this species is relatively fast; rapid mobilization of energy for gonadal recrudescence may be characteristic of species that spawn more than once in a season. Whether recrudescence was more rapid at 10° or 18°C was not investigated, nor are there sufficient data to indicate whether an optimal temperature exists for the completion of gonadal recrudescence. However, the data presented here show that gonadal recrudescence will occur over a wide temperature range (10°-20°C). This gonadal responsiveness to a wide range of temperatures may reflect an adaptation to the labile thermal environment of this species.

Active gametogenesis was maintained at low temperatures regardless of photoperiod. After treatment at a low temperature in May (Figure 4), more male fish were in the prespawning condition at the longer photoperiod. In the same experiment, however, a short photoperiod was more effective in maintaining vitellogenesis (Figure 4). Perhaps these results reflect a true photoperiod influence, but because of the variable gonadal conditions of the beginning controls no conclusive statements can be advanced. In fact, experiments begun in January with fish revealing less variable gonadal conditions indicated that long and short photoperiod treatments maintained active gametogenesis equally well at low temperature. Photoperiod influences, however, could vary between January and May.

The question arises as to why all fish treated at low temperatures did not progress to the prespawning condition. One possible explanation is that many of the experiments discussed here were relatively short term. In many of the long-term experiments some of the fish could be stripped of ripe eggs and sperm. It is likely, however, that physical factors other than temperature and photoperiod, and also social factors, influence final gonadal maturation and spawning in this species. Indeed, Weisel (1947) has indicated that *Gillichthys* is territorial and has an elaborate courtship behavior. In addition, de Vlaming (1971b) has shown that salinity changes and changes in the availability of food can alter the rate of gametogenesis in *Gillichthys*. Thus, the failure of many of the experimental fish to completely attain the prespawning condition was probably due to the absence of certain conditions in the laboratory sit-

uation. Unfortunately, no data are available on the effects of exogenous factors on the frequency of spawning, fecundity, egg size, or survivorship of the fry in this species, nor are data available on the influence of environmental factors on the spawning act. For a complete understanding of the role of the environment in the physiology and ecology of reproduction in *Gillichthys*, examination of these parameters is needed.

The data presented here indicate that temperature may be the proximate factor regulating the *Gillichthys* reproductive cycle. Zambrano (1971) found that the secretory activity of the pituitary gonadotrophic cells is altered by temperatures, and this provides further support for this suggestion. However, since fish in their natural habitat experience large diurnal temperature fluctuations, the experiments reported here are not conclusive. In addition, *Gillichthys* is capable of regulating its body temperature by behavioral means (de Vlaming, 1971a). These experiments do set the physiological limits with regard to the influence of temperature on reproduction. Understanding the ecological meaning of temperature in reproductive cycling requires experimentation with diurnally fluctuating temperature; experiments of this nature are reported elsewhere (de Vlaming, 1972c).

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KINDS AND ABUNDANCE OF FISH LARVAE IN THE EASTERN TROPICAL PACIFIC ON THE SECOND MULTIVESSEL EASTROPAC SURVEY, AND OBSERVATIONS ON THE ANNUAL CYCLE OF LARVAL ABUNDANCE

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ABSTRACT

This is the second and concluding paper dealing with kinds and abundance of fish larvae in the eastern tropical Pacific based on collections made on EASTROPAC survey cruises. Main emphasis is placed on the composition and abundance of fish larvae on the second multivessel EASTROPAC cruise, occupied by three research vessels during August-September 1967. This cruise, spaced 6 months after EASTROPAC I, affords interesting comparisons of composition and relative abundance of fish larvae during two contrasting periods of the year. Counts of fish larvae per haul on EASTROPAC II were about 50% greater than on EASTROPAC I; species composition, however, was strikingly similar in the two surveys.

A portion of the EASTROPAC pattern, lying between long 119° to 98°W and lat 20°N to 3°S, was covered on four additional monitoring cruises—providing coverage of this more restricted area on six cruises, spaced at 2-month intervals, between February 1967 and January 1968. Essentially the same kinds of fish larvae were taken on each of the six coverages of the monitoring pattern, and for most species the range in relative abundance during the annual cycle was 3× or less.

This report deals with the composition and relative abundance of fish larvae in the eastern tropical Pacific Ocean collected on the second multivessel survey cruise made as part of EASTROPAC, during August-September 1967. For brevity, the cruise is referred to in this report as EASTROPAC II (ETP II). This cruise, conducted 6 months after EASTROPAC I (ETP I), deals with the composition of fish larvae at a contrasting period of the annual spawning cycle in tropical waters (Ahlstrom, 1971).

Three research vessels participated in ETP II: *Washington* operated by the Scripps Institution of Oceanography occupied the outer pattern, *Undaunted* of the National Marine Fisheries Service occupied the middle pattern, and *Rockaway* operated by the Coast Guard took the inner pattern (Figure 1).

The coverage during ETP II was less extensive than that of the four vessels of ETP I. One major line of stations of ETP I was omitted from ETP II, that along long 126°W, and the coverage below the equator was abbreviated in the two outer patterns, with lines ending at lat 10°S or 5°S.

Comparison of the composition, relative abundance, and distributions of fish larvae at different periods of the year in tropical waters is a primary objective of this report. The major comparison is with fish larvae obtained on ETP I (Ahlstrom, 1971); all of the 355 ETP II collections and an equivalent number of ETP I collections can be used to show similarities and differences in the composition of the larval fish fauna during two contrasting periods of the year.

A portion of the EASTROPAC pattern was occupied by the National Marine Fisheries Service research vessel, *David Starr Jordan*, on

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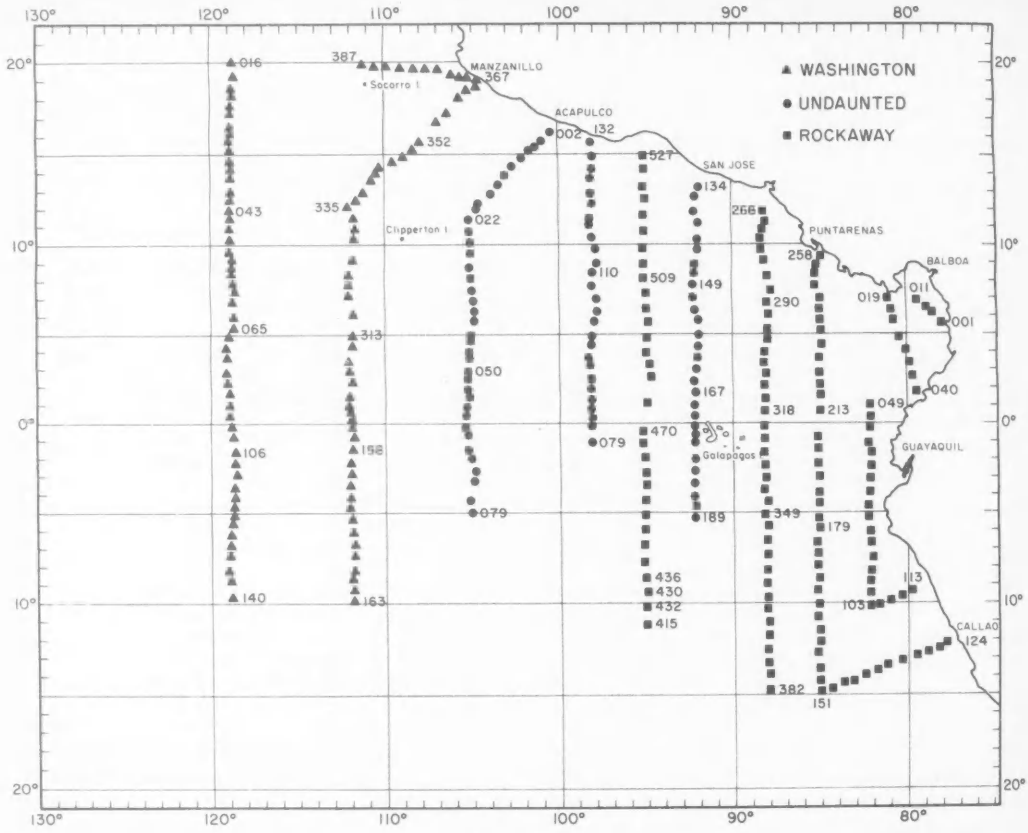

FIGURE 1.—Location of plankton stations occupied by three research vessels participating in the second multivessel EASTROPAC survey (ETP II). Symbols for vessels indicated in legend above. Samples collected by *Washington* are numbered as 45.000 series (for example 45.016, 45.140, 45.387), samples from *Undaunted* as 46.000 series, from *Rockaway* as 47.000 series.

monitoring cruises, spaced at bimonthly intervals between the multivessel cruises; coverages equivalent to the monitoring pattern were summarized for ETP I and ETP II, in order to compare the results of six bimonthly coverages of the same area (Figure 2). The monitoring pattern lacked coverage in the nearshore portion of the EASTROPAC pattern that was occupied by the inner vessel on multivessel surveys. Additional seasonal information about composition and relative abundance of fish larvae in this area was supplied by a "zig-transect" of 50 stations occupied by the RV *Oceanographer* of the Environmental Science Services Administration during November 1967—2 to 3 months after ETP II coverage of this area (Figure 2).

The methods of making zooplankton hauls on ETP II were identical to those previously described for ETP I (Ahlstrom, 1971). This paper deals solely with collections obtained from oblique hauls made with a net, 1-m mouth diameter, constructed of 505 μ nylon (Nitex) cloth, with approximately a 5:1 ratio of effective straining surface, i.e., pore area to mouth area.

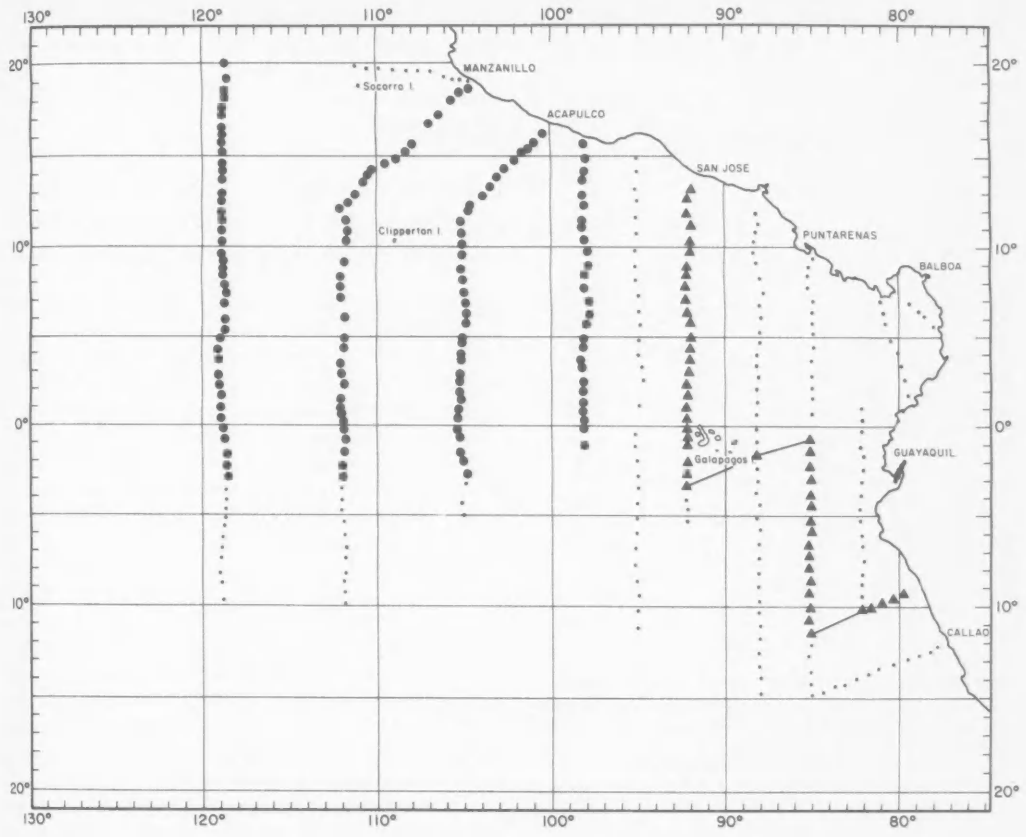

FIGURE 2.—Location of monitoring pattern (large solid circles), occupied between multivessel EASTROPAC cruises at 2-month intervals by *David Starr Jordan*, and of zig-transect pattern (triangles) occupied by *Oceanographer* during November 1967, superimposed on ETP II pattern.

As on ETP I, this net was paired in an assembly frame with a finer-meshed 0.5-m net. Each tow attempted to obtain a uniform sampling of zooplankton in the water column between the surface and approximately 200-m depth. The net assembly was lowered to depth by paying out 300 m of towing cable and then retrieved at a uniform rate. The depth reached by the net was estimated from the angle of stray (departure from the vertical) of the towing cable. The average depths of haul taken by the three research vessels are summarized in Table 1. Only slightly over two-thirds of the hauls were lowered to depths of 200 m or more and about one-eighth were taken at depths shallower than 180 m. Based on variation in depths sampled, speed of hauling was controlled less consistently on ETP II as compared with ETP I.

Four plankton collections were made each day with the paired net-assembly, at about 6-hr intervals. Timing of hauls was not coordinated between research vessels (Table 2). Usually *Rockaway* spaced the four hauls at approximately 0500, 1030, 1700, and 2300; hauls from *Wash-*

TABLE 1.—Depths of paired oblique pankton hauls taken by the three research vessels in EASTROPAC II (net lowered by paying out 300 m of towing cable).

Average depth of haul (m)	Number of hauls taken at each depth interval from			
	Washington 45.000 Series	*Undaunted* 46.000 series	*Rockaway* 47.000 Series	All vessels
80.1- 90.0	--	1	--	1
90.1-100.0	--	--	--	--
100.1-110.0	--	--	--	--
110.1-120.0	--	1	--	1
120.1-130.0	--	2	--	2
130.1-140.0	1	--	--	1
140.1-150.0	1	--	3	4
150.1-160.0	2	4	1	7
160.1-170.0	--	5	4	9
170.1-180.0	7	4	6	17
180.1-190.0	6	4	3	13
190.1-200.0	24	16	14	54
200.1-210.0	36	22	52	110
210.1-220.0	28	28	56	112
220.1-230.0	5	6	7	18
230.1-240.0	1	--	1	2
240.1-250.0	--	--	1	1
250.1-260.0	--	--	1	1
260.1-270.0	--	2	--	2
Total	111	95	149	355

TABLE 2.—Hour of day that paired oblique plankton hauls were made from the three research vessels participating in EASTROPAC II (midtime of haul used).

Hour of day	Number of hauls taken during each hour of the day			
	Washington	*Undaunted*	*Rockaway*	All vessels
0001-0100	10	10	8	28
0101-0200	4	0	1	5
0201-0300	1	0	3	4
0301-0400	0	1	3	4
0401-0500	0	10	14	24
0501-0600	5	8	15	28
0601-0700	12	3	4	19
0701-0800	5	1	0	6
0801-0900	2	0	1	3
0901-1000	1	0	6	7
1001-1100	1	0	21	22
1101-1200	10	14	6	30
1201-1300	11	11	1	23
1301-1400	3	0	1	4
1401-1500	3	0	2	5
1501-1600	2	0	12	14
1601-1700	0	0	16	16
1701-1800	10	22	4	36
1801-1900	9	3	1	13
1901-2000	5	0	0	5
2001-2100	2	0	3	5
2101-2200	1	0	5	6
2201-2300	0	0	11	11
2301-2400	14	12	11	37
Total	111	95	149	355

ington usually were taken at approximately 0630, 1200, 1800, and 2400; and hauls from *Undaunted* at 0500, 1200, 1730, and 2400. At least some hauls were taken during every hour of the day.

EFFECTIVENESS OF SAMPLING FISH LARVAE IN DAYLIGHT HAULS AS COMPARED WITH NIGHT HAULS

Catches of fish larvae for selected families in day hauls compared to night hauls or to hauls taken within ± 1 hr of sunrise or sunset are summarized in Table 3. For all categories of larvae combined, the catch was 212.0 larvae per daytime haul and 480.4 larvae per night haul, a difference in catch of 2.27×. Hauls taken within ± 1 hr of sunrise or sunset had an average catch of 347.0 larvae, intermediate between day and night catches.

Difference between day and night collections was somewhat less than for ETP I; on that survey the average count of larvae in night hauls was 2.76× as many as in day hauls (Ahlstrom 1971, Table 4). On both surveys gonostomatid larvae had the most marked differences in catches between night hauls and day hauls: 4.3× as many, on the average, in night collections compared with day on ETP I, 2.9× as many in night collections on ETP II. Night-day differences in catch per haul of myctophid larvae were less marked between the two surveys: 3.0× on ETP I as compared with 2.6× on ETP II. Night-day differences in average catches of bathylagid larvae were similar on the two multivessel surveys: 1.5× as many per haul on the average, in night collections compared with day collections. Sternoptychid larvae, which were sampled almost as well in day hauls as in night hauls on ETP I, showed a somewhat greater night-day difference on ETP II: 1.7× for ETP II as compared with 1.2× for ETP I.

Scombrid larvae were taken in lesser numbers per haul in both day and night hauls on ETP II compared with ETP I; in contrast to ETP I, however, (where a night-day difference of 3.7× was observed) no difference was obtained in night and day collections on ETP II.

TABLE 3.—Comparison of occurrences (positive hauls) and catches (original counts) of fish larvae in day hauls, night hauls, and hauls taken within 1 hr of sunrise or sunset, summarized for selected families.

Family or group	Day hauls			Night hauls				Hauls within ± 1 hr of sunrise or sunset			Total hauls		
	Number positive hauls	Total larvae	Average number per occupancy ($\bar{D}$)	Number positive hauls	Total larvae	Average number per occupancy ($\bar{N}$)	$\bar{N}/\bar{D}$	Number positive hauls	Total larvae	Average number per occupancy	Number positive hauls	Total larvae	Average number per occupancy
Bathylagidae	114	1,802	13.1	110	2,607	20.2	1.5	74	1,482	16.8	298	5,891	16.6
Gonostomatidae	131	4,896	35.5	125	13,264	102.8	2.9	86	6,095	69.3	342	24,255	68.3
Sternoptychidae	104	2,005	14.5	104	3,136	24.3	1.7	69	2,244	25.5	277	7,385	20.8
Chauliodontidae	18	68	0.5	23	86	0.7	1.4	15	53	0.6	56	207	0.6
Idiacanthidae	58	211	1.5	70	307	2.4	1.6	53	277	3.1	181	795	2.2
Other stomiatoidei	78	412	3.0	83	447	3.5	1.2	54	248	2.8	215	1,107	3.1
Myctophidae	136	13,847	100.3	128	33,167	257.1	2.6	88	16,995	193.1	352	64,009	180.3
Paralepididae	84	851	6.2	95	1,110	8.6	1.4	68	574	6.5	247	2,535	7.1
Scopelarchidae	47	83	0.6	53	139	1.1	1.8	34	76	0.9	134	298	0.8
Melamphaidae	112	463	3.4	105	581	4.5	1.3	67	321	3.6	284	1,365	3.8
Bregmacerotidae	59	847	6.1	59	1,138	8.8	1.4	42	1,077	12.2	160	3,062	8.6
Exocoetidae	27	104	0.8	18	22	0.2	0.2	14	20	0.2	59	146	0.4
Trachypteridae	13	14	0.1	22	27	0.2	2.0	11	18	0.2	46	59	0.2
Apogonidae	21	112	0.8	26	94	0.7	0.9	19	77	0.9	66	283	0.8
Bramidae	20	29	0.2	28	43	0.3	1.5	19	24	0.3	67	96	0.3
Chiasmodontidae	31	60	0.4	43	106	0.8	2.0	26	71	0.8	100	237	0.7
Coryphaenidae	43	60	0.4	40	75	0.6	1.5	26	50	0.6	109	185	0.5
Nomeidae	83	483	3.5	85	642	5.0	1.4	61	335	3.8	229	1,460	4.1
Scombridae	14	92	0.7	25	94	0.7	1.0	16	62	0.7	55	248	0.7
Other identified	114	1,278	9.3	120	3,649	28.3	3.0	79	959	10.9	313	5,886	16.6
Unidentified	69	260	1.9	65	426	3.3	1.7	48	176	2.0	182	862	2.4
Disintegrated larvae	118	1,272	9.2	98	814	6.3	0.7	72	728	8.3	288	2,814	9.8
Total fish larvae	138	29,249	212.0	129	61,974	480.4	2.27	88	31,962	363.1	355	123,185	347.0

WATER TEMPERATURES ON EASTROPAC II

Water temperatures were available at 1-m intervals from the surface to about 750-m depth for each station at which an STD was used for determination of salinity and temperature. I selected three depths for tabulation and study: surface, 10 m, and 50 m. STD readings were available for 347 of the 355 plankton stations taken on ETP II. A chart of surface temperature for ETP II will be included in the EASTROPAC Atlas.

To facilitate discussion of distributions of fish larvae, I have found it convenient to divide the EASTROPAC area into quadrants with the north-south division at the equator and the east-west division at long 100°W. I will use these divisions when discussing distribution of temperatures on ETP II, except for separating out a narrow band of water at the equator (lat 2°N to 2°S). Within a quadrant the temperatures are summarized by 5° latitude, except near the equator (Table 4).

In some parts of the ETP II pattern, the thermocline was considerably deeper than 50 m, so that the temperature at 50 m was similar to that at the surface. At a few stations in the northeast quadrant, where the thermocline was almost at the surface, the temperature at 10 m was 5° to 10°C lower than at the surface. At most stations in this quadrant the thermocline was considerably shallower than 50-m depth, as attested by marked differences in temperature between the surface and 50 m (Table 5). Mixed layer depths on ETP II were illustrated in Blackburn, Laurs, Owen, and Zeitzschel (1970)—Figure 7 on page 27. A brief summary of the temperature structure is given by quadrant.

NORTHEAST QUADRANT, EXCEPT WITHIN 2° LATITUDE OF EQUATOR

Surface temperatures in this quadrant were high, ranging between 25.4° and 29.8°C (average 27.2°C). Temperatures at 10 m were usually the same or within ±0.5°C of the surface, although 10 stations showed differences of more than 1°C and 7 of those were 4.6° to 10.1°C lower. These marked differences are indications of very shallow thermoclines; five contiguous stations along long 88°W offshore from Puntarenas, Costa Rica, had such near-surface thermoclines.

At most stations the thermocline was shallower than 50 m; at 79 of 91 stations, the temperature at 50 m was 5° to 15°C lower than at the surface, and at half of these the temperature was between 10° to 15°C lower at 50 m.

NORTHWEST QUADRANT, EXCEPT WITHIN 2° LATITUDE OF EQUATOR

Surface temperatures in this quadrant, 24.8° to 29.7°C (average 27.6°C), were similar to those of the inshore quadrant. Highest surface temperatures, averaging 28.3°C, were encoun-

TABLE 4.—Range of temperatures at surface, 10 m, and 50 m summarized by 5° latitude or smaller intervals for both offshore (long 100°-119°W) and inshore (coast to long 98°W) for EASTROPAC II.

Latitude	Offshore: long 100°-119°W				Inshore: coast to long 98°W			
	No. stn.	Range in temperature (°C) at:			No. stn.	Range in temperature (°C) at:		
		Surface	10 m	50 m		Surface	10 m	50 m
15°-20°N	32	25.7-29.7	25.5-29.6	17.7-28.6	1	29.8	29.6	23.1
10°-15°N	30	26.3-29.8	26.0-29.4	16.7-27.9	23	26.4-29.7	19.7-29.6	14.0-26.7
5°-10°N	20	25.8-27.7	25.8-27.8	16.5-27.4	42	25.8-28.9	16.3-28.9	13.5-23.6
2°- 5°N	15	24.8-26.6	24.8-26.4	20.3-26.2	25	25.2-26.8	25.3-27.0	15.2-25.9
Total 2°-20°N	97	24.8-29.7	24.8-29.6	16.5-28.6	91	25.2-29.8	16.3-29.6	13.5-26.7
Equator 2°N-2°S	20	19.5-25.0	19.0-25.0	15.7-22.4	30	16.4-25.9	15.6-25.9	13.7-17.4
2°- 5°S	14	20.6-23.0	20.5-23.0	14.0-22.6	19	18.4-22.2	17.4-21.9	14.2-20.2
5°-10°S	16	22.9-24.9	22.7-24.9	22.4-24.9	30	16.3-21.5	16.3-21.5	14.6-21.4
10°-15°S	0	--	--	--	30	15.4-21.4	15.1-21.4	13.9-21.2
Total 2°-15°S	30	20.6-24.9	20.5-24.9	14.0-24.9	79	15.4-22.2	15.1-21.9	13.9-21.4

TABLE 5.—Summary of temperature differences within upper 50 m depth (differences in temperature at the surface and at two selected depths—10 m and 50 m) summarized by quadrants.

Area	No. stn.	Difference in temperature at the surface and at 10-m depth					Difference in temperature at the surface and at 50-m depth				
		0°C	0.1°-0.5°C	0.6°-1.0°C	1.1°-5.0°C	5.1°-10.1°C	0°C	0.1°-1.0°C	1.1°-5.0°C	5.1°-10.0°C	10.1°-15.0°C
NE Quadrant (lat 2°-16°N, coast to long 98°W)	90	38	39	3	4	6	0	2	9	40	39
NW Quadrant (lat 2°-20°N, long 100-119°W)	97	65	26	5	1	0	6	14	46	27	4
Equator (lat 2°N-2°S, coast to long 98°W)	30	19	0	1	2	0	0	0	10	19	1
Equator (lat 2°N-2°S, long 100-119°W)	20	9	9	2	0	0	0	1	13	6	0
SE Quadrant (lat 2°-15°S, coast to long 98°W)	79	61	15	2	1	0	20	31	27	1	0
SW Quadrant (lat 2°-10°S, long 100-119°W)	30	17	12	1	0	0	9	15	5	1	0

tered between lat 15° and 20°N. Temperatures at 10 m were usually the same as at the surface, and in only one instance was the difference as great as 1.3°C. Temperatures at 50 m were identical to, or within 1°C of, the surface temperatures at about 20% of the stations, all located between lat 2° and 10°N—these were stations with deep thermoclines. Temperature differences between the surface and 50 m exceeded 5°C at about 35% of the stations.

EQUATOR, LAT 2°N TO 2°S

Surface temperatures were variable, with 9.5°C range (16.4° to 25.9°C). Lowest surface temperatures, undoubtedly resulting from upwelling, were encountered seaward of the Galapagos Islands, between long 92° and 98°W, lat 0.5°N to 2.0°S, but cold water was also encountered farther offshore. Thermoclines were shallow at most stations inshore from the Galapagos Islands, the difference between surface and 50 m exceeded 5°C at about 63% of the stations, but the surface water was warmer than offshore.

SOUTHEAST QUADRANT, EXCEPT WITHIN 2° LATITUDE OF EQUATOR

Water temperatures were much lower in this quadrant than in the northeast quadrant. Few surface temperatures were as high as 20°C, and the average surface temperature was 18.7°C. The thermocline was usually deep. At 65% of the stations the temperature at 50 m was the same as that at the surface or was not more than 1°C colder.

SOUTHWEST QUADRANT, EXCEPT WITHIN 2° LATITUDE OF EQUATOR

Surface temperatures ranged from 20.6° to 24.9°C (average 21.0°C). Temperatures at 10 m were usually the same as that at surface or within 0.5°C. Temperatures at 50 m were identical to the surface at 30% of stations and within 1°C of the surface temperature at 80% of stations, indicative of a region of deep thermocline.

In summary, water temperatures were much higher north of the equator, than south of the equator. Surface temperatures averaged 8.5°C higher in the northeast quadrant than in the southeast quadrant. Offshore the differences were almost as great; surface temperatures averaged 6.6°C higher in the northwest quadrant than in the southwest quadrant.

As noted in the paper dealing with ETP I collections, information is mostly lacking on depth distribution of fish larvae in the eastern tropical Pacific. Because of the marked variation in depth of thermocline encountered in different

parts of the EASTROPAC pattern, ranging from near-surface to deep, it is anticipated that depth distribution of larvae will be markedly affected by the temperature structure. A carefully planned study of depth distribution of larvae in the eastern tropical Pacific in relation to temperature and thermocline depth is badly needed. Lacking this, it is difficult to meaningfully relate larval distributions to temperature.

A REVIEW OF SIGNIFICANT PAPERS DEALING WITH ADULT FISHES OF THE EASTROPAC AREA

A working knowledge of the adult fishes of an oceanic region is a necessary prerequisite to meaningful study of the fish larvae of that region. Most larval series, initially, are established by working backwards from larger identified specimens (late-larvae or early juveniles) to early-stage larvae. Until recently shore fishes of the eastern tropical Pacific were much better known than deep-sea fishes, e.g., studies by Meek and Hildebrand (1923, 1925, 1928) for Panama and Hildebrand (1946) for Peru. Shore fishes, however, were not an important element of the EASTROPAC ichthyoplankton.

A major contribution to our knowledge of eastern Pacific fishes was made by Garman (1899), who worked up the fishes collected on the *Albatross* Expedition of 1891 to the west coasts of Mexico, Central and South America, and off the Galapagos Islands. Garman dealt with 180 species of fish, most new to science; about a third of these were pelagic, oceanic fishes. Included among the latter are the two most common pelagic fishes, *Diogenichthys laternatus* and *Vinciguerria lucetia*, in the eastern tropical Pacific, based on their abundance as larvae.

The second oceanographic expedition of the *Pawnee* to the eastern Pacific in 1926 added materially to our knowledge of the deep-sea fishes. Several of the species described by Parr (1931) from these collections are common as larvae in EASTROPAC plankton hauls, including *Bathylagus nigrigenys*, *Diaphus pacificus*, *Lampanyctus idostigma*, *L. parvicauda*, and *Scopelarchoides nicholsi*.

The New York Zoological Society sponsored several expeditions to the eastern Pacific which stimulated papers on Pacific Myctophidae by Beebe and Vander Pyle (1944) and on ceratioid fishes by Beebe and Crane (1947). The paper on myctophids contains information on taxonomy, biology, and zoogeography of 24 species of myctophids of which none were new. The paper by Beebe and Crane on deep-sea ceratioid fishes dealt with 24 species belonging to six families, of which 10 were new.

The ceratioid fishes of the Gulf of Panama had received attention previously: the Danish research vessel *Dana* had occupied several very productive stations in the Gulf of Panama in 1922, from which Regan (1926) described 18 species of ceratioids, mostly new. Bertelsen (1951) reported taking early life history stages of 23 kinds of ceratioids from the Gulf of Panama in *Dana* collections from its round-the-world expedition of 1928-30.

Information on fishes off Peru was obtained on the Yale South American Expedition of 1953. Morrow (1957a) gave an annotated list of 104 shore fishes, 21 new to the Peruvian fauna, and Morrow (1957b) gave an annotated list of 18 mid-depth fishes.

Bussing (1965) reports on 15 pelagic trawl hauls made on *Eltanin* cruises taken off the South American coast in 1962 and 1963 between lat 3° and 35°S. The collections contained 100 species, representing 33 families. Four trawl hauls were made within the EASTROPAC area; only one yielded substantial numbers of specimens. This was *Eltanin* Station 34 at lat 7°45′ to 7°48′S, long 81°23′W, from which 45 species were obtained.

Haedrich and Nielsen (1966) provided annotated identifications of 32 species (21 families) of fishes from stomachs of *Alepisaurus* collected at 19 stations by exploratory longline fishing from the Japanese RV *Shoyo Maru*. Four collections were obtained within the EASTROPAC area, and the other 15 between lat 20° and 40°S.

Craddock and Mead (1970) reported on collections made along two transects through the

southern portion of the Peru Current off Chile at lat 34°S. They provide annotated identifications of 133 species. Although these transects were south of the EASTROPAC area, many of the species also occur in the EASTROPAC area.

Parin (1971) reports on collections of midwater fishes of the Peru Current zone collected on the fourth cruise of RV *Akademik Kurchatov*. He lists about 150 species representing 33 families. Collections were obtained between lat 5°N and 30°S, in a broad coastal band, extending offshore to long 90°W. Distributions are illustrated for 24 species.

In addition to the above, a number of references dealing with particular species of genera or families of eastern Pacific fishes are cited in the body of the text, or were referred to in Ahlstrom (1971).

NUMBER OF FISH LARVAE OBTAINED ON EASTROPAC II

Fish larvae were obtained in all collections (355) made with the 1-m plankton net on ETP II; counts of larvae per haul ranged from 1 to 2,864, and averaged 347. Four collections contained 10 or fewer larvae, and 22 collections contained 1,000 or more specimens in each (Table 6).

Abundance of fish larvae according to latitude and proximity to shore within the EASTROPAC pattern is summarized in Table 7. The same grouping of stations by latitude (5° except near the equator) and longitude (inshore-offshore) is used as in Table 4 (temperature summary table). Subtotals provide a rough separation into quadrants.

Larvae were taken in greatest abundance in the northeast quadrant, particularly between lat 5° and 10°N; in this latter area, with an average surface temperature of 27.1°C, larvae averaged 639 per haul. Larvae were less abundant in the southeast quadrant, with numbers decreasing southward and averaging only 118 larvae per haul between lat 10° and 15°S (average surface temperature, 18.1°C).

Larvae were much less abundant offshore, in the northwest quadrant, averaging slightly over 40% as many per haul as in the inshore (northeast) quadrant. Surface temperatures, however, were quite similar.

Near the equator (lat 2°N to 2°S), larvae were moderately abundant inshore (434 per haul), and the decrease in the abundance offshore was not as marked as in other areas (362 per haul). This is not surprising, since this was an area of upwelling.

In the southwest quadrant (lat 2° to 10°S, long 110° to 119°W), there was a decrease in abundance toward the south. However, this quadrant was poorly sampled on ETP II. When compared to inshore coverage of the same latitude (lat 2° to 10°S), abundance of larvae per haul averaged about 62% as many.

Fish larvae averaged more per haul on ETP II as compared with comparable coverage on ETP I, 347.0 versus 231.9 larvae per haul; the increase in abundance was reflected in all parts of the EASTROPAC pattern.

The majority of large collections of fish larvae were made at stations with shallow thermoclines and relatively high mixed layer water

TABLE 6.—Relative numbers of fish larvae obtained over the three vessel patterns occupied on EASTROPAC II; last column gives comparable counts for EASTROPAC I.

No. of fish larvae per haul	*Washington* 45.000 Series	*Undaunted* 46.000 Series	*Rockaway* 47.000 Series	All patterns — EASTROPAC II	Comparable Coverage — EASTROPAC I
0	0	0	0	0	4
1-10	1	0	3	4	6
11-100	29	16	27	72	122
101-1,000	78	72	107	257	214
1,001 and over	3	7	12	22	9
Total	111	95	149	355	355
Average no. larvae per haul	224.0	400.3	404.7	347.0	231.9

TABLE 7.—Total catches of fish larvae (actual counts) taken on EASTROPAC II summarized by latitude (5° except near equator) and longitude (offshore or inshore).

Latitude	Offshore: long 100°-119°W			Inshore: coast to long 98°W		
	Number stations occupied	Number of larvae per haul		Number stations occupied	Number of larvae per haul	
		Range	Mean		Range	Mean
15°-20°N	32	31-1,048	219.0	1	130	130.0
10°-15°N	30	58- 481	159.1	23	37-2,242	435.4
5°-10°N	21	21-1,128	237.4	42	61-2,864	639.1
2° -5°N	16	93-1,217	359.6	28	141-1,975	555.1
Total 2°-20°N	99	21-1,128	227.5	94	37-2,864	558.8
Equator 2°N-2°S	21	30-1,506	361.5	30	1-1,513	434.4
2°- 5°S	14	79- 817	268.5	20	6-1,061	431.4
5°-10°S	16	8- 472	178.2	30	27-1,002	287.3
10°-15°S	--	--	--	31	4- 579	118.0
Total 2°-15°S	30	8- 817	220.4	81	4-1,061	258.1
Grand total	150	8-1,506	244.8	205	1-2,864	421.8

temperatures. Over 60% of the larger collections of fish larvae (750 or more larvae) were taken at stations with mixed layer temperatures in excess of 26°C and mixed layer depths of 35 m or less.

Unfortunately, information is lacking on the depth distribution of fish larvae in the eastern tropical Pacific in relation to thermocline depth, hence it is not known whether most kinds were limited in depth distribution to the upper mixed layer, as reported for California Current waters (Ahlstrom, 1959).

KINDS OF FISH LARVAE OBTAINED ON EASTROPAC II

With some interesting exceptions, the same kinds of larvae were obtained on ETP II as on ETP I, and Table 8, the principal summary table covering ETP II larvae, contains essentially the same families as its counterpart for ETP I. The table lists 53 families and 6 composite categories including 3 orders or suborders and a catchall category—other identified. For the latter, composition by families is given in subsequent tables or in text discussions. Altogether, fish larvae of 82 families were represented in ETP II collections. As on ETP I, larvae of 10 families contributed over 90% (91.0 on ETP II) of the total; 9 of these families were among the first 10 on both EASTROPAC surveys and had similar rankings. The first 10 families on ETP II were as follows: Myctophidae, 52.0%; Gonostomatidae, 19.7%; Sternoptychidae, 6.0%; Bathylagidae, 4.8%; Bregmacerotidae, 2.5%; Paralepididae, 2.0%; Nomeidae, 1.2%; Melamphaidae, 1.1%; Engraulidae, 1.1%; and Idiacanthidae, 0.6%. Engraulidae is the only family on this list that did not rank among the first 10 on ETP I. The sole displacement from the previous list is the family Scombridae, which slipped in ranking from fifth in ETP I to twentieth in ETP II. Of the remaining 9%, 2.3% were too damaged (disintegrated) to identify, 0.7% could not be identified (these were mostly very small larvae), and the remainder, about 6%, belonged to the other 72 families.

The displacement of Scombridae from among the 10 most abundant families on ETP II left only one perciform family, Nomeidae, among those contributing 1% or more of the total. Only a moderate number of perciform families have become widely distributed in offshore oceanic waters. Among these, larvae of Gempylidae contributed 0.3% of the total on ETP II; Apogonidae, 0.2%; Chiasmodontidae, 0.2%; Coryphaenidae, 0.1%; Trichiuridae, 0.1%; and Bramidae, 0.1%.

The basic data on the kinds and number of fish larvae obtained in the 355 ETP II collections are contained in Appendix Tables 1 to 6. These are keyed to Table 8 and to other tables in this report.

The data presented in this paper represent but the first step in utilizing eggs and larvae collections for resource evaluation.

TABLE 8.—Occurrences and counts of fish larvae taken in oblique 1.0-m plankton hauls on the second multivessel EASTROPAC survey (EASTROPAC II), summarized by family or larger grouping and by research vessel.

Family or larger grouping[1]	Basic station data contained in Appendix Table no.		Distribution shown in Figure no.	*Washington* 45.000 Series		*Undaunted* 46.000 Series		*Rockaway* 47.000 Series		Total EASTROPAC II	
	By family or larger grouping	By genus or species		No. positive hauls	No. larvae	No. positive hauls	No. larvae	No. positive hauls	No. larvae	No. positive hauls	No. larvae
1 Albulidae		4		0	0	0	0	2	9	2	9
*2 Clupeidae		4	3	0	0	7	185	2	85	9	270
*3 Engraulidae		4	3	4	15	2	3	29	1,342	35	1,360
*4 Argentinidae		3		14	21	14	32	4	5	32	58
*5 Bathylagidae	1	3	4	74	352	90	1,277	134	4,262	298	5,891
*6 Gonostomatidae	1	3	5-7	108	9,079	94	7,095	140	8,081	342	24,255
*7 Sternoptychidae	1			75	1,882	74	1,941	128	3,562	277	7,385
*8 Astronesthidae	3		5	10	16	15	30	17	28	42	74
*9 Chauliodontidae	1		8	10	25	10	15	36	167	56	207
*10 Idiacanthidae	1		9	49	275	62	219	70	301	181	795
*11 Other Stomiatoidei	1	3		60	245	64	219	86	570	210	1,034
12 Chlorophthalmidae				0	0	3	5	1	3	4	8
*13 Evermannellidae	3		10	9	47	7	19	1	1	17	67
*14 Myctophidae	1	2	3, 8, 11-14	111	9,546	95	21,082	146	33,381	352	64,009
15 Neoscopelidae				5	5	2	3	5	7	12	15
*16 Paralepididae	1	3		91	497	80	1,002	76	1,036	247	2,535
*17 Scopelarchidae	1			39	103	45	92	50	103	134	298
*18 Scopelosauridae	3		10	0	0	11	46	29	344	40	390
*19 Synodontidae	4		5	1	1	2	5	11	53	14	60
20 Alepisauridae				1	1	1	2	2	2	4	5
*21 Anguilliformes	5		14, 15	16	33	30	42	35	76	81	151
*22 Melamphaidae	1		18	79	262	83	408	122	695	284	1,365
*23 Trachichthyidae	3			0	0	0	0	11	70	11	70
24 Holocentridae				3	10	0	0	0	0	3	10
*25 Bregmacerotidae	1			63	379	47	1,624	50	1,059	160	3,062
26 Macrouridae				1	1	3	3	5	5	9	9
*27 Scomberesocidae	3		14	0	0	0	0	27	153	27	153
28 Exocoetidae	1			15	26	22	33	22	87	59	146
29 Trachypteridae	1			10	10	16	20	20	29	46	59
*30 Apogonidae	1			28	178	24	73	14	32	66	283
31 Balistidae	3			1	1	3	6	1	1	5	8
32 Blenniidae				0	0	0	0	5	5	5	5
33 Bramidae	1			21	31	17	24	29	41	67	96
*34 Carangidae	4		17	8	28	8	59	20	137	36	224
35 Carapidae	4			0	0	0	0	7	7	7	7
36 Chiasmodontidae	1			25	46	25	45	50	146	100	237
*37 Coryphaenidae	1			37	56	34	62	38	67	109	185
*38 Gempylidae		3	4	36	59	30	64	46	247	112	370
*39 Gobiidae	4			5	65	11	33	37	286	53	384
40 Labridae	4		10	9	21	9	10	14	26	32	57
41 Mugilidae	4			0	0	0	0	5	16	5	16
*42 Nomeidae	1			68	357	64	391	97	712	229	1,460
*43 Ophidiidae				0	0	7	9	31	72	38	81
44 Polynemidae	4			2	21	2	5	3	5	7	31
45 Pomacentridae	4			1	5	0	0	4	5	5	11
46 Sciaenidae	4			0	0	2	93	8	34	10	127
*47 Scombridae	1			15	70	24	89	16	89	55	248
48 Scorpaenidae	4			5	18	16	93	37	133	58	244
49 Serranidae	4			3	13	6	13	17	54	26	80
50 Sphyraenidae				0	0	1	2	1	8	2	10
*51 Tetragonuridae[2]		3	17	5	5	5	6	1	1	11	12
*52 Trichiuridae		3	4, 17	3	3	2	2	44	181	49	186
*53 Bothidae		4	5	7	19	28	307	35	364	70	690
*54 Cynoglossidae		4		2	5	16	109	38	248	56	362
55 Ostraciontidae	3			14	49	1	1	0	0	15	50
*56 Lophiiformes	6		18	25	42	33	56	56	145	114	243
*57 Other identified				7	11	3	3	13	37	23	51
58 Unidentified larvae	1			48	171	56	265	78	426	182	862
59 Disintegrated larvae	1			96	753	77	809	115	1,252	288	2,814
Total				111	24,859	95	38,032	149	60,294	353	123,185

[1] Categories preceded by an asterisk are discussed in the text.
[2] Discussed in text under 42, Nomeidae.

TABLE 9.—Standardized counts of fish larvae compared with unstandardized (original) counts, summarized for selected families (see Appendix Table 8 for standardized haul factors).

Family or larger grouping	Standardized counts					Unstandardized counts	
	45.000 series	46.000 series	47.000 series	Total standardized counts	Percentage of total	Total unstandardized counts	Percentage of total
Bathylagidae	1,132	3,569	14,427	19,128	4.8	5,891	4.8
Gonostomatidae	31,525	19,347	26,717	77,589	19.5	24,255	19.7
Sternoptychidae	6,529	5,977	12,321	24,827	6.3	7,385	6.0
Chauliodontidae	97	43	589	729	0.2	207	0.2
Idiacanthidae	901	699	996	2,596	0.7	795	0.6
Other Stomiatoidei	914	732	2,061	3,707	0.9	1,107	0.9
Myctophidae	31,015	62,775	111,787	205,577	51.8	64,009	52.0
Paralepididae	1,712	2,724	3,511	7,947	2.0	2,535	2.1
Scopelarchidae	350	281	342	973	0.2	298	0.2
Melamphaidae	818	1,227	2,223	4,268	1.1	1,365	1.1
Bregmacerotidae	1,259	5,772	3,210	10,241	2.6	3,062	2.5
Exocoetidae	78	104	245	427	0.1	146	0.1
Trachypteridae	32	63	93	188	<0.1	59	<0.1
Apogonidae	636	228	110	974	0.2	283	0.2
Bramidae	99	77	138	314	0.1	96	0.1
Chiasmodontidae	161	123	501	785	0.2	237	0.2
Coryphaenidae	185	194	227	606	0.2	185	0.2
Nomeidae	1,132	1,235	2,345	4,712	1.2	1,460	1.2
Scombridae	237	296	284	817	0.2	248	0.2
Other identified	1,704	3,893	13,204	18,801	4.7	5,886	4.8
Unidentified	590	827	1,274	2,691	0.7	862	0.7
Disintegrated larvae	2,604	2,405	4,255	9,264	2.3	2,814	2.3
Total fish larvae	83,710	112,591	200,860	397,161	100.0	123,185	100.1

Relative abundance of fish as larvae is not necessarily proportional to their relative abundance as adults. A number of parameters would have to be evaluated if counts of eggs and larvae of a species are to be used in determining the biomass of adult populations. These include fecundity (preferably given as number of eggs spawned in relation to fish weight—such as number of eggs spawned per gram of female weight); egg size, which influences size and state of development at hatching; duration of time spent in plankton both as egg stage and as larva as related to temperature of development; mortality rates during embryonic and larval stages; size at transformation; length of spawning season; age structure of population; etc.

I am assuming that the relative abundances of larvae of a given species are comparable from cruise to cruise in the EASTROPAC area. I am further assuming that comparisons of relative abundance within a family, as for example among myctophid or among scombrid larvae, will reflect their relative abundance as adults within reasonable limits. I, however, would caution against taking comparisons between families too literally until essential parameters are evaluated for each.

Actual counts of larvae rather than standardized values are used in tabulations throughout the paper, except Table 9. Table 9 compares summations of larvae of selected families based on standardized values with summations based on actual counts. These families make similar percentage contributions to the larval catch whether based on standardized counts or actual counts.

COMPARISON OF COMPOSITION AND RELATIVE ABUNDANCE OF LARVAE IN EASTROPAC II AND EASTROPAC I COLLECTIONS

In order to keep comparisons between the two EASTROPAC multivessel cruises completely relevant, the following stations lacking counterparts in ETP II were omitted from ETP I summations: Stations 11.146 to 11.328 of the outer pattern occupied by *Argo*, Stations 12.122 to 12.164 of the adjacent pattern occupied by *David Starr Jordan*, and Stations 13.095 to 13.155 of the next to inner pattern occupied by *Rockaway*. The remaining stations, by happy coincidence, total 355, are identical to the

TABLE 10.—Comparison of occurrences and relative abundance of fish larvae on EASTROPAC II (355 stations) with comparable coverage on EASTROPAC I (355 stations) summarized by family or larger grouping.

Family or larger grouping	EASTROPAC II			EASTROPAC I		
	No. positive hauls	No. larvae	Average no. per haul	No. positive hauls	No. larvae	Average no. per haul
Clupeidae	9	270	0.8	10	81	0.2
Engraulidae	35	1,360	3.8	10	205	0.6
Argentinidae	32	58	0.2	38	81	0.2
Bathylagidae	298	5,891	16.6	275	4,742	13.4
Gonostomatidae	342	24,255	68.3	333	18,380	51.8
Sternoptychidae	277	7,385	20.8	240	4,923	13.9
Astronesthidae	42	74	0.2	11	12	<0.1
Chauliodontidae	56	207	0.6	59	124	0.3
Idiacanthidae	181	795	2.2	132	855	2.4
Other Stomiatoidei	210	1,034	2.9	157	428	1.2
Chloropthalmidae	4	8	<0.1	1	4	<0.1
Evermannellidae	17	67	0.2	10	13	<0.1
Myctophidae	352	64,009	180.3	346	39,249	110.6
Paralepididae	247	2,535	7.1	218	1,456	4.1
Scopelarchidae	134	298	0.8	109	273	0.8
Scopelasauridae	40	390	1.1	6	13	<0.1
Synodontidae	14	60	0.2	10	41	0.1
Anguilliformes	81	151	0.4	66	138	0.4
Melamphaidae	284	1,365	3.8	235	703	2.0
Trachypteridae	11	70	0.2	0	0	0
Bregmacerotidae	160	3,062	8.6	132	1,587	4.5
Scomberesocidae	27	153	0.4	1	1	<0.1
Exocoetidae	59	146	0.4	66	164	0.5
Trachypteridae	46	59	0.2	33	35	0.1
Apogonidae	66	283	0.8	37	135	0.4
Balistidae	5	8	<0.1	2	3	<0.1
Bramidae	67	96	0.3	40	49	0.1
Carangidae	36	224	0.6	31	183	0.5
Carapidae	7	7	<0.1	3	3	<0.1
Chiasmodontidae	100	237	0.7	48	97	0.3
Coryphaenidae	139	185	0.5	67	97	0.3
Gempylidae	112	370	1.0	59	110	0.3
Gobiidae	53	384	1.1	60	530	1.5
Labridae	32	57	0.2	28	40	0.1
Mugilidae	5	16	<0.1	5	9	<0.1
Nomeidae	229	1,460	4.1	159	900	2.5
Polynemidae	7	31	0.1	5	11	<0.1
Sciaenidae	10	127	0.4	4	12	<0.1
Scombridae	55	248	0.7	163	1,840	5.2
Scorpaenidae	58	244	0.7	47	162	0.5
Serranidae	26	80	0.2	26	252	0.7
Sphyraenidae	2	10	<0.1	3	3	<0.1
Tetragonuridae	11	12	<0.1	2	3	<0.1
Trichiuridae	49	186	0.5	19	48	0.1
Bothidae	70	690	1.9	56	199	0.6
Cynoglossidae	56	362	1.0	63	304	0.9
Lophiiformes	114	243	0.7	108	214	0.6
Other identified	76	247	0.7	—	159	0.4
Unidentified larvae	182	862	2.4	170	723	2.0
Disintegrated larvae	288	2,814	7.9	291	2,725	7.7
Total larvae	355	123,185	347.0	351[1]	82,319	231.9

[1] Total stations 355 of which 351 contained larvae (positive hauls), 4 were negative.

count of stations occupied on ETP II. Hence, comparisons between the two cruises can be based on either the average number of larvae per haul or on "total numbers of larvae" of each category inasmuch as equal numbers of stations contributed to the totals.

Comparisons of occurrence and relative abundance of fish larvae in the ETP II pattern (all stations) with comparable coverage for ETP II are summarized by family or larger groupings in Table 10.

Nearly 50% more fish larvae were obtained per haul, on the average, in ETP II (347.0 larvae) as compared with ETP I (231.9 larvae). The larvae of most families of fishes were taken in larger numbers on ETP II than on ETP I, and larvae of several families were taken in markedly larger numbers. The striking exception to this trend was afforded by scombrid larvae; only 13.5% as many scombrid larvae were obtained in ETP II collections as in similar coverage of ETP I.

Families showing the largest increase in total numbers of larvae on ETP II compared with ETP I included Engraulidae (1,360 to 205 larvae), Scomberesocidae (153 to 1 specimen), Scopelosauridae (390 to 13 larvae), Evermannellidae (67 to 13 larvae), Astronesthidae (75 to 13 larvae), Trachichthyidae (70 to 0 larvae), Sciaenidae (127 to 12 larvae), Trichiuridae (186 to 48 larvae), Gempylidae (370 to 110 larvae), and Clupeidae (270 to 81 larvae). For the majority of these, the increase in relative abundance of larvae was most marked in the inner pattern occupied by *Rockaway*. The species compositions involved in these increases, when known, are discussed later under the respective families.

For the majority of families, however, the increase in abundance of larvae on ETP II was moderate, seldom as much as double; for a third of the families, counts of larvae were not much different during the two contrasting periods of the year; thus the similarity in abundance of larvae during the two periods is the striking feature of this comparison.

COMPARISON WITH EASTROPAC MONITORING CRUISES

The portion of the eastern tropical Pacific pattern that could be covered by a single research vessel on surveys averaging 45 days was occupied at bimonthly intervals on four monitoring cruises by *David Starr Jordan*. The cruises were numbered as follows: 20.000 series for the April-May 1967 monitoring cruise, 30.000 series for the June-July monitoring cruise, 50.000 for the October-November 1967 monitoring cruise, and 60.000 for the December 1967-January 1968 monitoring cruise. The monitoring pattern is shown superimposed on ETP II stations in Figure 2; it consisted of four station lines all ending at lat 3°S. The outer line along long 119°W extended from lat 20°N, the inner line along long 98°W, off the Mexican coast (ca. lat 17°N). The two middle lines along long 105° and 112°W were doglegs veering coastward from about lat 12° or 13°N—one line ending up off Manzanillo, Mexico, and the other off Acapulco, Mexico.

Coverage equivalent to the monitoring pattern was determined for ETP I and II. For ETP I the following stations were occupied: 11.022 to 11.118 (35), 12.002 to 12.109 (50), 12.209 to 12.264 (24), and 13.187 to 13.265 (28); total 137 stations. For ETP II comparable coverage was obtained from Stations 45.016 to 45.114 (41), 45.191 to 45.365(37), 46.002 to 46.069 (36), and 46.079 to 46.132(27); total 141 stations.

COMPARISON OF LARVAL COMPOSITION IN MONITORING PATTERN VERSUS LARGER EASTROPAC PATTERN

In Table 11 a comparison is made for both ETP I and ETP II of the average number of larvae per haul and percentage contribution of larvae of the more important fish families in the monitoring pattern as compared with the total pattern occupied on ETP II.

The correspondence between relative abundance and composition of larvae in the monitoring pattern as compared with the larger ETP pattern is closer for ETP I collections than ETP II. The average abundance of larvae in the monitoring pattern on ETP I was 92% as large as for the larger ETP I pattern (equivalent to the coverage obtained on ETP II). The more abundant kinds of larvae—myctophids, gonostomatids, and sternoptychids—had similar average abundances per haul and similar percentage contributions in the monitoring pattern as compared with the more extensive ETP I coverage. Of the remaining seven families used in this com-

TABLE 11.—Comparison of relative abundance of fish larvae (average number per haul) in the monitoring pattern as compared with the total pattern occupied on EASTROPAC II and equivalent EASTROPAC I for more abundant families.

	EASTROPAC II						EASTROPAC I					
	Monitoring pattern (141 hauls)			Total pattern (355 hauls)			Monitoring pattern (137 hauls)			Pattern equivalent to total EASTROPAC II (355 hauls)		
Family	Average no. per haul	%	Rank	Average no. per haul	%	Rank	Average no. per haul	%	Rank	Average no. per haul	%	Rank
Myctophidae	116.4	45.6	1	180.3	52.0	1	104.9	49.0	1	110.6	47.7	1
Gonostomatidae	77.9	30.5	2	68.3	19.7	2	48.6	22.7	2	51.8	22.3	2
Sternoptychidae	12.8	5.0	3	20.8	6.0	3	14.2	6.6	3	13.9	6.0	3
Bathylagidae	4.9	1.9	5	16.6	4.8	4	6.4	3.0	5	13.4	5.8	4
Bregmacerotidae	3.4	1.3	7	8.6	2.5	5	6.6	3.1	4	4.5	1.9	6
Paralepididae	8.2	3.2	4	7.1	2.0	6	4.8	2.3	6	4.1	1.8	7
Nomeidae	4.2	1.7	6	4.1	1.2	7	3.6	1.7	7	2.5	1.1	8
Melamphaidae	2.9	1.1	9	3.8	1.1	8	1.5	0.7	10	2.0	0.9	10
Idiacanthidae	3.0	1.2	8	2.2	0.6	10	2.8	1.3	8	2.4	1.0	9
Scombridae	0.6	0.2	10	0.7	0.2	ca. 20	2.4	1.1	9	5.2	2.2	5
Other	20.8	8.2		34.5	9.9		18.1	8.5		21.5	9.3	
Total	255.1	99.9		347.0	100.0		213.9	100.0		231.9	100.0	

parison, four were taken in somewhat higher numbers in the monitoring pattern and three in the more extensive ETP I coverage. Among the latter, less than half as many scombrid larvae were taken per haul in the smaller pattern as compared with the larger.

The average abundance of larvae in the monitoring pattern on ETP II was only 73.5% as many as for the total ETP II pattern. Larvae of three families were slightly more abundant in the monitoring pattern than in the total ETP II pattern, including Gonostomatidae, Paralepididae, and Idiacanthidae; larvae of Scombridae and Nomeidae were about equally abundant in the two patterns. Four families of fishes, however, including Myctophidae and Sternoptichidae, were less abundant in the monitoring pattern as compared with the total ETP II pattern. Caution has to be exercised in the applications made of data from the monitoring pattern alone.

TEMPORAL CHANGES IN ABUNDANCE IN MONITORING PATTERN

Data from six successive bimonthly coverages of the monitoring patterns are exceptionally useful for determining the annual reproductive cycles of fishes in tropical waters. Data on relative abundance (average number per haul) are summarized for the 10 most common families in Table 12 and for selected genera and species in Table 13. The time period covered by each of the six surveys is indicated in these tables, and will be used for identifying cruises in the discussion.

The first thing to note is the range in abundance of total larvae on the six cruises: the highest abundance, 255.1 larvae per haul (August-September) was slightly less than double the lowest abundance, 133.1 larvae per haul in December-January. Range in abundance of larvae of each of the 10 families during the yearly cycle will be briefly discussed.

Myctophidae ranked first in all cruises, although barely so in the cruise made during June-July. The highest average number of larvae per haul, 116.4, obtained in August-September was almost double the lowest value, 58.7 larvae obtained in December-January. Myctophid larvae were as low as 37.9% of the total larvae (June-July), as high as 57.1% (October-November), and had an overall percentage contribution of 47.5%.

Gonostomatidae ranked second in all cruises; the lowest abundance per haul, 32.6 larvae in October-November, was less than half the highest value, 77.9 larvae per haul in August-September. Percentage contribution ranged between 18.5% (October-November) and 37.7% (June-July) and averaged 26.9%.

Sternoptychidae ranked third in abundance

TABLE 12.—Relative abundance and percentage contribution of fish larvae of the 10 most common families within that portion of EASTROPAC area covered on six successive bimonthly cruises between February 1967 and January 1968.

Family	ETP multivessel I[1] (Feb.-Mar.)		ETP monitoring cruise #20 (Apr.-May)		ETP monitoring cruise #30 (June-July)		ETP multivessel II[2] (Aug.-Sept.)		ETP monitoring cruise #50 (Oct.-Nov.)		ETP monitoring cruise #60 (Dec.-Jan.)		Six cruises - ETP monitoring area	
	Average no. per haul	%	Average no. per haul	%	Average no. per haul	%	Average no. per haul	%	Average no. per haul	%	Average no. per haul	%	Average no. per haul	%
Myctophidae	104.9	49.0	100.4	50.7	67.6	37.9	116.4	45.6	100.7	57.1	58.7	44.1	91.2	47.5
Gonostomatidae	48.6	22.7	50.6	25.6	67.3	37.7	77.9	30.5	32.6	18.5	33.7	25.3	51.6	26.9
Sternoptychidae	14.2	6.6	17.1	8.6	9.5	5.3	12.8	5.0	13.5	7.6	12.9	9.7	13.3	7.0
Bathylagidae	6.4	3.0	3.9	2.0	2.9	1.6	4.9	1.9	3.2	1.8	2.6	2.0	4.0	2.1
Paralepididae	4.8	2.3	4.1	2.1	5.3	3.0	8.2	3.2	3.2	1.8	4.8	3.6	5.1	2.7
Nomeidae	3.6	1.7	3.5	1.8	5.1	2.9	4.2	1.7	1.5	0.9	2.4	1.8	3.4	1.8
Bregmacerotidae	6.6	3.1	1.3	0.7	2.6	1.4	3.4	1.3	3.1	1.7	2.4	1.8	3.2	1.7
Idiacanthidae	2.8	1.3	2.9	1.5	2.0	1.1	3.0	1.2	1.1	0.6	1.5	1.1	2.2	1.1
Melamphaidae	1.5	0.7	1.8	0.9	1.6	0.9	2.9	1.1	1.7	1.0	1.3	1.0	1.8	0.9
Scombridae	2.4	1.1	1.4	0.7	1.0	0.6	0.6	0.2	1.3	0.8	1.4	1.1	1.4	0.7
Other	18.1	8.5	10.8	5.4	13.5	7.6	20.8	8.2	14.5	8.2	11.4	8.5	14.8	7.7
Total	213.9	100.0	197.8	100.0	178.4	100.0	255.1	99.9	176.4	100.0	133.1	100.0	192.0	100.1

[1] ETP I —stations 11.022-11.118 (35), 12.002-12.109 (50), 12.209-12.264 (24), and 13.187-13.265 (28).
[2] ETP II — stations 45.016-45.114 (41), 45.191-45.365 (37), 46.002-46.069 (36), and 46.079-46.132 (27).

in all cruises. The average abundance per haul ranged from 9.5 larvae (June-July) to 17.1 (April-May), a range of less than two times.

Bathylagid smelts were represented in the monitoring pattern by a single species, *Bathylagus nigrigenys* Parr. Average abundance of larvae per haul ranged from 2.6 (December-January) to 6.4 (February-March) and averaged 4.0 larvae. Larvae of Bathylagidae usually ranked fifth in abundance.

Paralepididae usually ranked fourth in relative abundance; the lowest average abundance per haul was 3.2 larvae in October-November, and the highest was 8.2 larvae in August-September.

Nomeidae ranked variously fifth to eighth in relative abundance, with an overall ranking of sixth. The range in average abundance per haul was from 1.5 (October-November) to 5.1 larvae (June-July) and averaged 3.4 larvae.

Bregmacerotidae showed the widest variation in abundance, 1.3 larvae (April-May) to 6.6 larvae (February-March); consequently they ranked variously between fourth and tenth in relative abundance. Larvae of the most common species of *Bregmaceros* within the monitoring pattern, *B. bathymaster*, tend to cluster with occasional samples having rather large numbers of larvae. Variability in sampling due to chance encounters of clusters of larvae could be of greater magnitude than that resulting from actual changes in reproductive activity during the year.

Idiacanthidae, usually ranked eighth in abundance per haul from 1.1 (October-November) to 2.9 larvae (April-May), with an overall average of 2.2 larvae per haul.

Melamphaidae ranked variously between seventh and tenth, with an overall rank of ninth. The lowest abundance, 1.3 larvae per haul in December-January, was less than half the highest, 2.9 larvae in August-September.

Scombridae in the monitoring area ranked either ninth or tenth in relative abundance of larvae on all cruises; the lowest average abundance, 0.6 larvae per haul in August-September, is only a fourth of the highest average value, 2.4 larvae in February-March.

Larvae of these 10 families made up over 92% of the fish larvae in the monitoring pattern. In all instances, larvae of all principal families were taken throughout the year. The spread between the highest and lowest abundance values for larvae of these principal families of fishes was usually less than three times, and for Myctophidae and Sternoptychidae, was less than double.

A similar seasonal pattern of abundance was observed for individual genera or species (Table 13). I found it helpful to arrange the 18 ge-

TABLE 13.—Relative abundance (average number per haul) of pelagic fish larvae of selected genera and species within that portion of EASTROPAC area covered on six successive bimonthly cruises between February 1967 and January 1968.

Genus or species	ETP multi-vessel I (Feb.-Mar.)	ETP monitor cruise #20 (Apr.-May)	ETP monitor cruise #30 (June-July)	ETP multi-vessel II (Aug.-Sept.)	ETP monitor cruise #50 (Oct.-Nov.)	ETP monitor cruise #60 (Dec.-Jan.)	Range	Average six cruises
	Average number per haul							
Bathylagus nigrigenys	6.4	3.9	2.9	4.9	3.2	2.6	2.6- 6.4	4.0
Cyclothone spp.	3.7	3.0	3.7	3.0	1.2	2.7	1.2- 3.7	2.9
Diplophos taenia	0.6	0.4	0.6	0.6	0.7	0.4	0.4- 0.7	0.6
Vinciguerria lucetia	43.3	45.8	62.5	71.9	30.3	30.0	30.0- 71.9	47.3
Chauliodus sp.	0.4	0.1	0.1	0.2	0.2	0.2	0.1- 0.4	0.2
Idiacanthus sp.	2.8	2.9	2.0	3.0	1.1	1.5	1.1- 3.0	2.2
Bathophilus filifer	0.9	0.6	0.6	1.3	0.6	0.9	0.6- 1.3	0.8
Diogenichthys laternatus	51.1	63.0	37.4	68.6	62.2	31.8	31.8- 68.6	52.4
Gonichthys tenuiculus	0.7	0.8	0.3	0.7	0.5	0.2	0.2- 0.8	0.5
Hygophum atratum	2.5	1.0	1.5	1.5	1.4	1.1	1.0- 2.5	1.5
Hygophum proximum	3.0	2.7	2.0	2.7	3.0	1.1	1.1- 3.0	2.4
Notolychnus valdiviae	2.8	2.4	2.0	2.0	1.6	1.5	1.5- 2.8	2.0
Notoscopelus resplendens	0.9	0.9	0.5	1.1	0.6	1.0	0.5- 1.1	0.8
Symbolophorus evermanni	1.4	0.4	1.0	1.9	1.2	1.0	0.4- 1.9	1.2
Triphoturus sp.	0.9	0.8	0.5	0.8	0.3	0.3	0.3- 0.9	0.6
Auxis spp.	2.2	1.1	0.7	0.5	1.1	1.1	0.5- 2.2	1.1
Coryphaena spp.	0.3	0.5	0.7	0.7	0.3	0.2	0.2- 0.7	0.4
Howella pammelas	0.8	1.1	1.3	1.6	0.6	0.4	0.4- 1.6	1.0
All others	89.2	66.4	58.1	88.1	66.3	55.1	55.1- 89.2	70.5
Total	213.9	197.8	178.4	255.1	176.4	133.1	133.1-255.1	192.4

nera and species of this table according to the magnitude of the seasonal change in abundance that each displayed.

Seasonal range in relative abundance between highest and lowest average number of larvae per haul:

Less than 2×: *Notolychnus valdiviae*

2.1 to 3×: *Bathylagus nigrigenys, Diplophos taenia, Vinciguerria lucetia, Idiacanthus* sp., *Bathophilus filifer, Diogenichthys laternatus, Hygophum atratum, Hygophum proximum, Notoscopelus resplendens, Triphoturus* sp.

3.1 to 4×: *Cyclothone* spp., *Chauliodus* sp., *Gonichthys tenuiculus, Coryphaena* spp., *Howella pammelas*

4.1 to 5×: *Symbolophorus evermanni, Auxis* spp.

Larvae of the above 18 genera and species were taken on all cruises throughout the year. Obviously, reproduction is a continuous process for all of these, varying in amount at different seasons of the year and at different latitudes, but never stopping entirely.

Larvae of two species dominated the collections from the monitoring pattern: those of the myctophid *Diogenichthys laternatus* and of the gonostomatid, *Vinciguerria lucetia*. Together these two species made up 44 to 56% of the total larvae in the monitoring pattern (Table 14).

The highest average abundance of larvae of the lanternfish, *Diogenichthys laternatus*, 68.6 larvae in August-September, was 2.5× as much as the lowest average abundance, 31.8 larvae in December-January. Larvae of this species ranked first in abundance between October and May, but were less abundant than larvae of *Vinciguerria lucetia* during June-September. Larvae of *Vinciguerria lucetia* had a range of 2.4× between their highest average abundance per haul, 71.9 larvae in August-September, and lowest, 30.0 larvae in December-January. A small but consistent change in abundance with season is evident for this species, with the peak period in June-September, the minimal period in October-January, and intermediate abundance of larvae in February-May.

The monitoring cruises were valuable in permitting us to establish the seasonal patterns of

TABLE 14.—Percentage contributions of larvae of the two most abundant species to the total catch of larvae in the monitoring pattern.

Cruise designation	Time of survey	Percentage contribution of larvae of		
		Vinciguerria lucetia	*Diogenichthys laternatus*	Combined
EASTROPAC I	Feb.-Mar.	20.2	23.9	44.1
20.000 series	Apr.-May	23.2	31.8	55.0
30.000 series	June-July	35.0	21.0	56.0
EASTROPAC II	Aug.-Sept.	28.6	26.9	55.1
50.000 series	Oct.-Nov.	17.2	35.3	52.5
60.000 series	Dec.-Jan.	22.5	23.9	46.4
	Annual	24.6	27.2	51.8

reproduction in oceanic, tropical fishes. Except for this, little more was gained from the repeated coverages that was not evident from any one of the six coverages. The same species composition was observed in all six cruises, and even the relative abundance of the various constituents did not change much. The similarity between cruises also extended to the geographic distributions of the various constituents which changed but little over time.

COMPARISON WITH RV *OCEANOGRAPHER* ZIG-TRANSECT

Although the average number of larvae per haul was almost identical for the *Oceanographer* collections and equivalent ETP II collections, 488.5 versus 487.8 larvae, and the kinds of larvae obtained were strikingly similar, the relative abundance of several categories was somewhat more variable than in the monitoring pattern (Table 15).

Similarities and differences in relative abundance of larvae during the two coverages can be shown from a consideration of the 10 families with highest abundance in the *Oceanographer* collections (Table 16).

Myctophidae.—The difference in relative abundance of Myctophidae larvae between *Oceanographer* and ETP II collections, 194.1 versus 273.9 larvae per haul, is almost entirely due to difference in relative abundance of larvae of *Diogenichthys laternatus*. Over 50% of *D. laternatus* larvae on ETP II were taken in four contiguous stations between lat 5°40′ and 7°44′N, with three collections exceeding 1,000 larvae and the largest with 2,505 larvae. Interestingly, the two *Oceanographer* collections containing more than 1,000 *D. laternatus* larvae were taken between lat 6° and 7°N; these were the only two stations occupied between lat 5°40′ and 7°44′N by *Oceanographer* in contrast to four collections from this rich area on ETP II.

Gonostomatidae.—The difference in relative abundance of Gonostomatidae larvae in the two occupancies of the zig-transect was again due principally to a single species, *Vinciguerria lucetia*. Although twice as many larvae of this species were taken in *Oceanographer* collections, an examination of the station record revealed that one collection, OP.036 with 2,046 larvae, accounted completely for the difference.

Clupeidae.—It is necessary to examine the species composition to evaluate differences between the two coverages (Table 17). Larvae of the sardine, *Sardinops sagax*, were taken in six contiguous stations near the Galapagos on ETP II, and averaged 29 larvae per positive haul, whereas only 1 sardine larva was obtained from the same area by *Oceanographer*. This species appears to have a period of peak spawning with reduced reproduction at other periods of the year. The contrast between the two collections of thread herring, *Opisthonema* sp., made at the station nearest the Mexican coast along long 92°W is the largest observed in EASTROPAC collections—2,730 larvae in the *Oceanographer* sample versus one larva in the ETP II collection. The larvae in the *Oceanographer* collection were intermediate-sized, 6 to 12.5 mm. Even allowing for the circumstance that clupeid larvae often occur in patches, this exceptionally large collection of larvae must have been obtained at a peak period of spawning of thread herring.

Bathylagidae.—Larvae of the two species of bathylagid smelts that occur in the area covered by the zig-transect, were similar in distribution and relative abundance in the two coverages. Larvae of *Bathylagus nigrigenys* were taken in all but three collections on each coverage, and average abundance per haul was almost identical, 26.3 versus 26.6 larvae (Table 17). Larvae of *Leuroglossus stilbius urotranus* had a more restricted distribution on both coverages, occurring between about 7°S and the equator, at sta-

TABLE 15.—Comparison of composition of catches of fish larvae in *Oceanographer* zig-transect, occupied in November-December 1967, with equivalent coverage by EASTROPAC II vessels during August-September 1967.

Family or larger grouping	*Oceanographer* (50 stations)			Equivalent ETP II coverage (48 stations)		
	No. positive hauls	No. larvae	Average no. per haul	No. positive hauls	No. larvae	Average no. per haul
Clupeidae	2	2,737	54.7	7	185	3.9
Engraulidae	6	760	15.2	15	381	7.9
Argentinidae	0	0	0	2	2	<0.1
Bathylagidae	47	2,308	46.2	45	2,005	41.8
Gonostomatidae	47	4,386	87.7	45	2,386	49.7
Sternoptychidae	39	976	19.5	40	1,093	22.8
Chauliodontidae	16	47	0.9	9	19	0.4
Idiacanthidae	15	27	0.5	28	58	1.2
Other stomiatoidei	28	209	4.2	32	274	5.7
Myctophidae	50	9,706	194.1	47	13,149	273.9
Paralepididae	28	556	11.1	25	320	6.7
Scopelarchidae	15	138	2.8	9	36	0.8
Scopelarsauridae	11	14	0.3	19	32	0.7
Synodontidae	1	3	0.1	3	7	0.1
Anguilliformes	10	18	0.4	16	23	0.5
Melamphaidae	43	243	4.9	40	274	5.7
Bregmacerotidae	1	470	9.4	9	1,455	30.3
Macrouridae	3	3	0.1	4	4	0.1
Exocoetidae	5	16	0.3	6	11	0.2
Scomberesocidae	1	1	<0.1	6	7	0.1
Trachypteridae	7	11	0.2	8	11	0.2
Apogonidae	1	1	<0.1	5	14	0.3
Bramidae	13	22	0.4	7	10	0.2
Carangidae	2	354	7.1	5	56	1.2
Chiasmodontidae	27	65	1.3	13	38	0.8
Coryphaenidae	8	8	0.2	8	13	0.3
Gempylidae	7	21	0.4	9	30	0.6
Gobiidae	6	42	0.8	12	35	0.7
Labridae	3	3	0.1	3	3	0.1
Nomeidae	37	185	3.7	27	155	3.2
Ophidiidae	6	10	0.2	5	6	0.1
Sciaenidae	4	34	0.7	4	96	2.0
Scombridae	7	82	1.6	10	41	0.9
Scorpaenidae	9	14	0.3	11	86	1.8
Serranidae	2	28	0.6	6	9	0.2
Sphyraenidae	1	1	<0.1	1	2	<0.1
Trichiuridae	4	4	0.1	8	10	0.2
Bothidae	14	67	1.3	17	227	4.7
Cynoglossidae	7	164	3.3	10	99	2.1
Lophiiformes	20	39	0.8	13	23	0.5
Other identified	6	104	2.1	12	23	0.5
Unknown larvae	21	53	1.1	21	100	2.1
Disintegrated larvae	42	488	9.8	42	606	12.6
Total larvae	50	24,417	488.5	48	23,414	487.8

tions occupied shoreward of the Galapagos Islands; the average abundance per haul was slightly higher in *Oceanographer* collections—19.9 versus 15.1 larvae.

Engraulidae—Larvae of *Engraulis ringens* were taken in more collections on ETP II (Table 17), but in lesser numbers per positive haul than in *Oceanographer* collections. The spawning period of the Peruvian anchovy is mostly between August and February (Einarsson and Rojas de Mendiola, 1967); both coverages were within this period of the year. Larvae of other engraulids were taken at the inner station off Mexico in both coverages, but in markedly larger numbers by *Oceanographer*. Larvae of Sternoptychidae, Melamphaidae, and Paralepididae had similar frequency of occurrence in the two coverages (Table 16); differences in relative abundance were small to moderate.

Carangid larvae were taken in more collec-

TABLE 16.—Comparison of occurrence and average abundance per haul of larvae of 10 families with highest relative abundance on *Oceanographer* zig-transect with equivalent coverage on ETP II.

Family	*Oceanographer* (50 stations)			Equivalent ETP II (48 stations)		
	No. positive hauls	Average no. per haul	Rank	No. positive hauls	Average no. per haul	Rank
Myctophidae	50	194.1	1	47	273.9	1
Gonostomatidae	47	87.7	2	45	49.7	2
Clupeidae	2	54.7	3	7	3.9	11
Bathylagidae	47	46.2	4	45	41.8	3
Sternoptychidae	39	19.5	5	40	22.8	5
Engraulidae	6	15.2	6	15	7.9	6
Paralepididae	28	11.1	7	25	6.7	7
Bregmacerotidae	1	9.4	8	9	30.3	4
Carangidae	2	7.1	9	5	1.2	--
Melamphaidae	43	4.9	10	40	5.7	8

tions on ETP II, 5 versus 2 (Table 16), but one of the two positive hauls at *Oceanographer* stations contained 353 larvae. This is considered a chance collection of a patch of larvae. Larvae of Bregmacerotidae were taken in only one *Oceanographer* collection, compared to nine on ETP II. Larvae of two species of *Bregmaceros* were represented in ETP II stations but only larvae of *B. bathymaster* were taken in large numbers. The single *Oceanographer* collection of 470 larvae of this species was made at the inner station off Mexico; two large collections of *B. bathymaster* larvae were made at the two inner stations off Mexico on ETP II (511 and 927 larvae). The principal difference in abundance of *Bregmaceros* larvae between the two coverages appears to be the chance collection of two patches versus one patch of *B. bathymaster* larvae.

I have gone into some detail in order to point up the influence of one or a few larger collections of larvae on the estimates of relative abundance (average number of larvae per haul) of several of the more abundant kinds of larvae in the zig-transect. Larvae of most kinds of fishes are patchily distributed, rather than randomly distributed. Variability associated with patchiness in distribution of larvae may be greater than variability due to temporal changes in reproductive activity. In this comparison, an example of temporal differences in reproductive activity is afforded by the sardine. The exceptionally large collection of thread herring larvae is certainly indicative of very heavy spawning off Mexico in late November; the single larva taken in the same area on ETP II (September 15) may actually be indicative of low reproductive activity or, contrariwise, may simply reflect the circumstance that most hauls of patchily distributed species contain few or no larvae. Striking examples of the influence of one or a few collections on the estimates of abundance of larvae in the two coverages of the zig-transect are afforded by larvae of the two most common species, *Vinciguerria lucetia* (one collection) and *Diogenichthys laternatus* (two collections). I interpret difference in abundance of both species in the two time periods involved to be due primarily to variability associated with patchy distribution of larvae rather than to temporal differences in reproductive activity.

COMMENTS ON LARVAE OF THE MAJOR FISH FAMILIES COLLECTED ON EASTROPAC II

As mentioned in an earlier section, the kinds of larvae obtained on the second multivessel EASTROPAC cruise are summarized in Table 8 by family or larger grouping and by research vessel. This table contains 59 categories: 53 families and 6 composite categories including 3 orders or suborders and those labelled "other identified," "unidentified larvae," and "disintegrated larvae." Only those categories preceded by an asterisk are commented upon in the text discussion that follows; these include 31 families and 4 composite categories. Each category retains the sequential number given to it in this table.

The number of families included in the four composite categories are as follows: other Stomiatoidei (2), Anguilliformes (7), Lophiiformes (10), and "other identified" (10). Hence a total of 82 families were identified from ETP II collections.

Basic data on the kinds and numbers of fish larvae obtained in the 355 ETP II stations are contained in Appendix Tables 1-6, and station data including location, date and time of collection, depth of haul, and standardized haul factors for these stations are given in Appendix Table 8.

TABLE 17.—Comparison of composition of selected families and orders of fish larvae in *Oceanographer* zig-transect versus equivalent ETP II collections.

Categories	*Oceanographer* (50 stations)			Equivalent ETP II coverage (48 stations)		
	No. positive hauls	No. larvae	Average no. per haul	No. positive hauls	No. larvae	Average no. per haul
Clupeidae						
Etrumeus acuminatus	1	6	0.1	3	7	0.1
Opisthonema sp.	1	2,730	54.6	1	1	<0.1
Sardinops sagax	1	1	<0.1	6	177	3.7
Engraulidae						
Engraulis ringens	5	283	5.7	13	378	7.9
Other Engraulidae	1	477	9.5	2	3	0.1
Bathylagidae						
Bathylagus nigrigenys	47	1,315	26.3	45	1,278	26.6
Leuroglossus stilbius urotranus	13	993	19.9	12	727	15.1
Gonostomatidae						
Cyclothone spp.	26	90	1.8	24	75	1.6
Ichthyococcus irregularis	10	19	0.4	12	16	0.3
Maurolicus muelleri	16	177	3.5	12	282	5.9
Vinciguerria lucetia	47	4,085	81.7	45	2,000	41.7
Other Gonostomatidae	8	15	0.3	6	13	0.3
Myctophidae						
Benthosema panamense	1	43	0.9	2	88	1.8
Diaphus spp.	22	57	1.1	11	37	0.8
Diogenichthys laternatus	47	7,314	146.3	43	11,317	235.8
Gonichthys tenuiculus	24	63	1.3	16	52	1.1
Hygophum atratum	6	15	0.3	1	5	0.1
Hygophum proximum	2	2	<0.1	3	3	0.1
Lampanyctus spp.	49	1,041	20.8	38	610	12.7
Myctophum aurolaternatum	19	65	1.3	8	43	0.9
Myctophum nitidulum	27	445	8.9	24	314	6.5
Notolychnus valdiviae	9	24	0.5	10	71	1.5
Notoscopelus resplendens	24	75	1.5	10	80	1.7
Protomyctophum sp.	6	9	0.2	5	10	0.2
Symbolophorus evermanni	20	96	1.9	19	49	1.0
Triphoturus spp.	35	205	4.1	26	321	6.7
Other incl. unidentified myctophids	17	44	0.9	17	73	1.5
Disintegrated myctophids	32	208	4.2	21	76	1.6
Anguilliformes						
Congridae	2	3	0.1	2	3	0.1
Nemichthyidae	3	4	0.1	5	5	0.1
Nettastomidae	1	1	<0.1	0	0	0
Ophichthidae	5	8	0.2	7	11	0.2
Xenocongridae	0	0	0	1	1	<0.1
Family uncertain	2	2	<0.1	2	3	0.1
Lophiiformes						
Caulophrynidae	0	0	0	1	1	<0.1
Ceratiidae	3	3	0.1	1	2	<0.1
Gigantactinidae	1	1	<0.1	2	2	<0.1
Linophrynidae	5	8	0.2	3	3	0.1
Melanocoetidae	7	8	0.2	5	6	0.1
Oneirodidae	5	8	0.2	6	8	0.2
Lophiidae	1	1	<0.1	1	1	<0.1
Family uncertain	7	10	0.2	0	0	0

A summary of these tables follows.

Appendix Table 1.—Counts of fish larvae, tabulated by family, for all stations occupied on EASTROPAC II. This table contains 22 categories including 18 families, 1 suborder, and 3 composite categories for "other identified larvae," "unidentified larvae," and "disintegrated larvae." The latter category includes larvae too damaged or disintegrated to identify with any certainty.

Appendix Table 2.—Counts of myctophid larvae, tabulated by genus or species, for all stations occupied on the second multivessel EASTROPAC cruise (ETP II). Myctophid larvae are tabulated by species for 13 kinds, by genus for 6 kinds, and 3 composite categories—"other

identified myctophids," "unidentified myctophids," and "disintegrated myctophids." A summary of this appendix table is contained in Table 19.

Appendix Table 3.—Counts of selected categories of fish larvae, tabulated by station, for all stations occupied on ETP II. Table contains 23 categories including 11 species, 5 genera, and 7 families. Of these, 12 were included in the category "other identified larvae" in Appendix Table 1, the remainder provide information on counts of larvae at the generic or specific level for several families listed in Appendix Table 1.

Appendix Table 4.—Summary of occurrences and numbers of larvae of 23 categories, limited in distribution to a broad coastal band or around offshore islands or banks. Only positive stations are included. These 23 categories were included under "other identified larvae" in Appendix Table 1.

Appendix Table 5.—Numbers and kinds of eel leptocephali (Anguilliformes) obtained on the second multivessel EASTROPAC cruise (ETP II), tabulated by family for all positive hauls. A summary of this table is given in Table 20.

Appendix Table 6.—Numbers and kinds of lophiiform larvae obtained on the second multivessel EASTROPAC cruise (ETP II) tabulated by family for all positive hauls. A summary of this table is given in Table 23.

Appendix Table 7.—7A contains counts of fish larvae, tabulated by family or larger grouping, for all stations occupied by *Oceanographer* on zig-transect; 7B contains station counts of myctophid larvae for same cruise, tabulated by genus or species; and 7C contains station counts of selected categories of fish larvae on same cruise.

Appendix Table 8.—Station data and standardized haul factors for second multivessel EASTROPAC cruise and for *Oceanographer* zig-transect. Included for each station are locality, date and time of collection, depth of haul, and standardized haul factor. The standardized haul factors are used to adjust original counts of larvae to the comparable standard of numbers of larvae in 10 m^3 of water strained per meter of depth fished. It should be noted that the mid-time of haul for each station is recorded as Pacific Standard Time. However, the symbols D (Daylight), N (Night), DT (Day Twilight), NT (Night Twilight) accurately reflect the local condition at each station. Twilight hauls were taken within 1 hr of local sunrise or sunset.

2. CLUPEIDAE
(9 occurrences, 270 larvae)

As on ETP I, three species of Clupeidae larvae were obtained. Larvae of the sardine, *Sardinops sagax* (Jenyns), (7 occurrences, 179 larvae) and round herring, *Etrumeus acuminatus* Gilbert, (3 occurrences, 7 larvae) were taken in the vicinity of the Galapagos Islands while larvae of the thread herring, *Opisthonema* sp., (2 occurrences, 84 larvae) were taken at two coastal stations off southern Mexico, with surface water temperatures of 28.7° and 29.3°C. Six of the occurrences of sardine larvae were at contiguous stations, along long 92°W, between lat 1°N and 3°S, just seaward of the Galapagos Islands (Figure 3). Surface water temperatures at these stations ranged between 16.4° and 19.3°C. We sampled the Galapagos sardine population on ETP II, at a period of rather high reproductive activity.

3. ENGRAULIDAE
(35 occurrences, 1,360 larvae)

The Peruvian anchovy, *Engraulis ringens* Jenyns, (25 occurrences, 1,307 larvae) also was sampled on ETP II during a period of high reproductive activity (Figure 3). Einarsson and Rojas de Mendiola (1967) determined that the spawning season of the Peruvian anchovy extended from August to March, hence the early part of the 1967-68 spawning season was sampled on ETP II and the close of the previous spawning season on ETP I. Surface temperatures at positive stations ranged between 15.4° and 18.8°C. Larvae of other engraulids (10 occurrences, 53 larvae) were taken at nearshore stations over a wide area between lat 20°N and the equator.

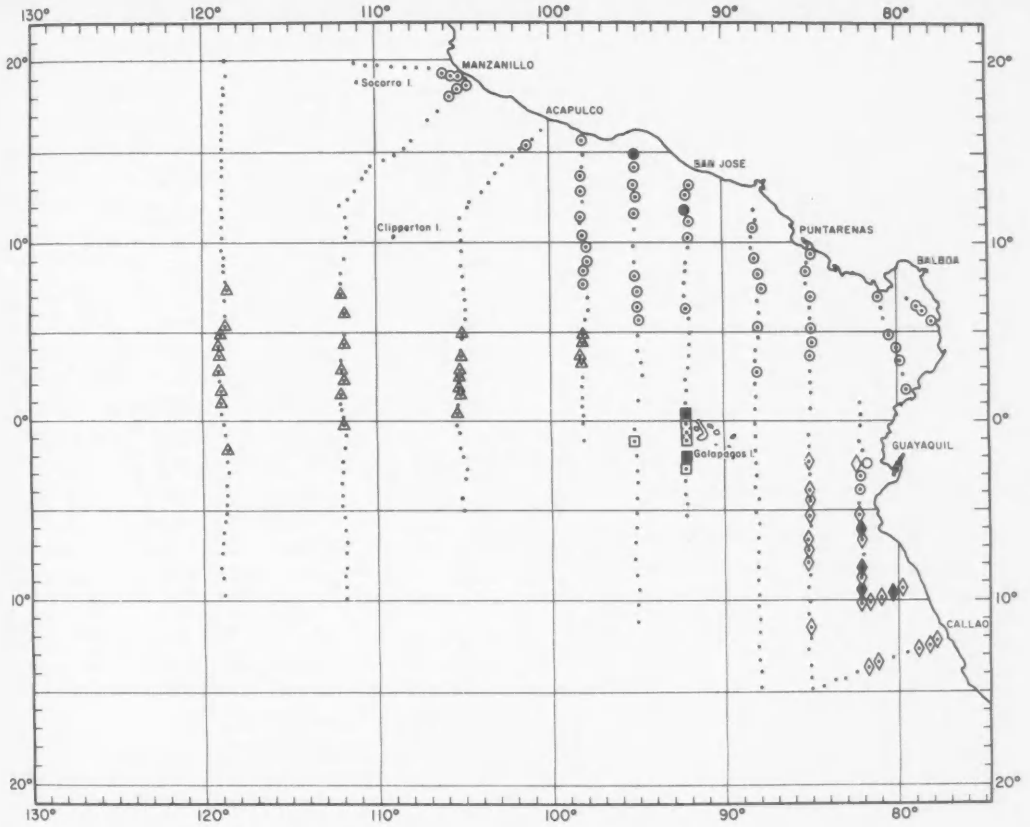

FIGURE 3.—Distribution of larvae of the clupeid, *Sardinops sagax* (open square with dot, 1-50 larvae; closed square, 51 or more larvae), of the engraulid, *Engraulis ringens* (open diamond with dot, 1-100 larvae; closed diamond, 101 or more larvae), of the myctophid, *Myctophum asperum* (open triangle with dot), and of the bothid flatfish, *Syacium ovale* (open circle with dot, 1-100 larvae; large solid circles, 101 or more larvae). Small solid circles represent other stations occupied on ETP II.

4. ARGENTINIDAE
(32 occurrences, 58 larvae)

In contrast to ETP I, from which three kinds of argentinid larvae were obtained, only one kind, *Nansenia* sp. A, was obtained on ETP II. Larvae of *Nansenia* were taken in an offshore equatorial band, between lat 8°N and 7°S. This distribution is closely similar to that illustrated for ETP I (Ahlstrom, 1971, Figure 2).

5. BATHYLAGIDAE
(298 occurrences, 5,891 larvae)

Larvae of two species of bathylagid smelts were taken on ETP II: *Bathylagus nigrigenys* Parr (293 occurrences, 3,787 larvae) and *Leuroglossus stilbius urotranus* (Bussing) (29 occurrences, 2,104 larvae).

In comparable coverage on ETP I, 2,852 larvae of *B. nigrigenys* were taken in 269 collections. The distribution of larvae on the two coverages was strikingly similar (Ahlstrom, 1971, Figure 3). On the two outer lines, occu-

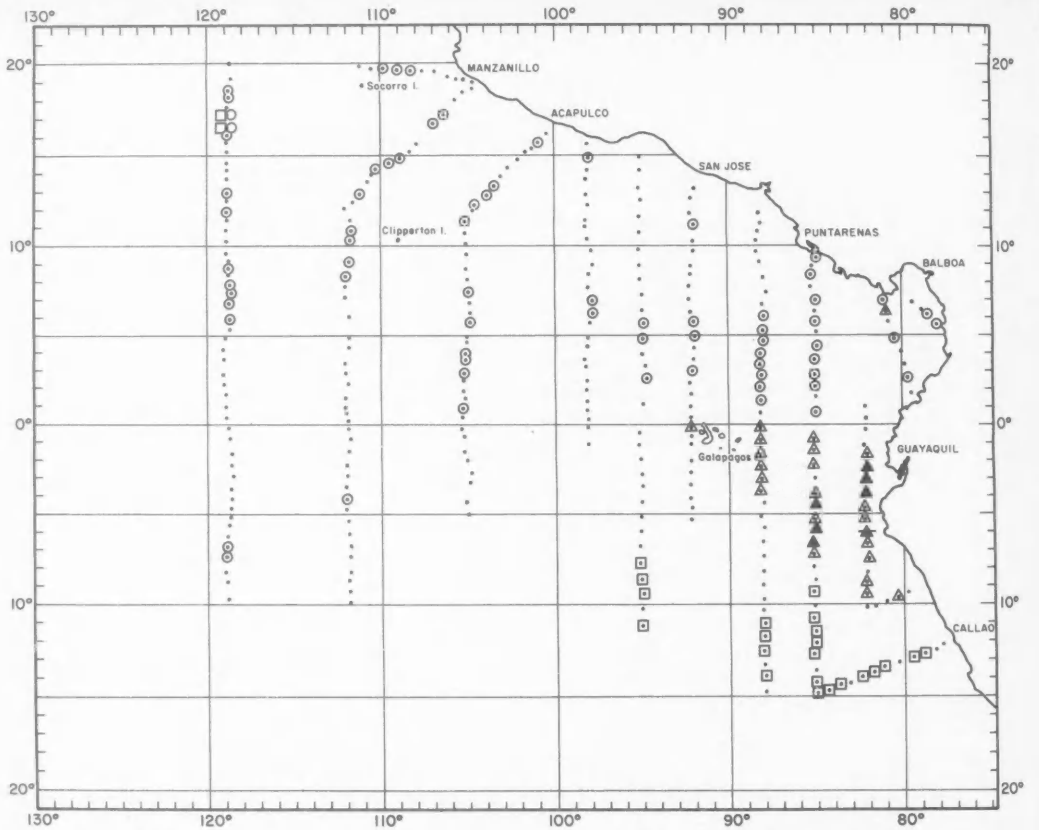

FIGURE 4.—Distribution of larvae of the bathylagid, *Leuroglossus stilbius urotranus* (open triangle with dot, 1-100 larvae; closed triangle, 101-500 larvae, and triangle with bisecting line, 501 or more), of the gempylid, *Gempylus serpens* (open circle with dot), and of the trichiurid, *Diplospinus multistriatus* (open square with dot). Small solid circles represent other stations occupied on ETP II.

pied by *Washington*, no larvae of *B. nigrigenys* were taken below ca. lat. 4°S. Absence of larvae of this species from the South Pacific central water mass was not as conclusively documented as on ETP I, primarily because of the paucity of coverage within the central water mass on ETP II. Counts of larvae exceeded 100 specimens per haul in five samples, taken between 0° and lat 3°S and long 85° to 92°W.

Larvae of *Leuroglossus stilbius urotranus* were taken in 29 collections; all but 2 of which were obtained in a compact area shoreward of the Galapagos Islands between 0° and lat 10°S (Figure 4). The distribution of larvae of this species is one of the few that shows a striking contrast between ETP I and ETP II. On ETP I about half of the occurrences were to the north of the equator between 0° and lat 8°N (18 occurrences, 218 larvae—Ahlstrom, 1971, Figure 2), compared with only one occurrence, one larva in this area on ETP II. The distribution south of the equator was essentially similar on both surveys; on ETP I, 1,672 larvae were taken in 19 collections between 0° and lat 14°S, with the heaviest concentration of larvae in hauls taken between lat 3° and 6°S.

6. GONOSTOMATIDAE
(342 occurrences, 24,255 larvae)

Gonostomatid larvae, exceeded in abundance only by myctophid larvae, were obtained in 97% of the ETP II collections and contributed 19.7% of the total fish larvae. The relative abundance and frequency of occurrences of larvae belonging to 10 genera of gonostomatids are summarized by vessel patterns in Table 18. The last two columns of this table give information concerning occurrence and relative abundance of gonostomatid larvae of the same genera for comparable coverage on ETP I.

Little change in abundance, distribution, or frequency of occurrence was shown by larvae of *Cyclothone* spp. and *Diplophos taenia* Günther, although both were slightly more abundant on ETP I. Average abundance of larvae of *Vinciguerria* spp. was about one-third greater than on equivalent ETP I, and almost three times as many larvae of *Maurolicus muelleri* (Gmelin) were obtained on ETP II. An interesting instance of a marked difference in seasonal abundance of larvae of a gonostomatid fish was found for larvae of *Yarrella argenteola* (Garman). Larvae of this species were taken in 17 collections on ETP II (Figure 6), whereas only one specimen was obtained on ETP I.

Araiophos eastropas Ahlstrom and Moser
(1 occurrence, 35 larvae)

The single record on ETP II is from the southernmost station occupied by *Washington* on its outer line at lat 9°45'S, long 118°59'W. On ETP I, all occurrences of larvae of this species were taken between lat 10° and 18°S along long 119° and 126°W (Ahlstrom, 1971, Figure 4). Hence, it was exciting to obtain the single ETP II collection of larvae of *Araiophos* at the only station in the pattern that bordered on the distributional limits of this species as determined from ETP I collections.

Cyclothone spp.
(187 occurrences, 972 larvae)

Larvae of *Cyclothone* spp. were taken in about an equal number of collections in the two surveys, 187 on ETP II versus 190 on equivalent coverage of ETP I, and in rather similar abundance—2.7 larvae per haul on ETP II as compared with 3.1 on equivalent ETP I. The distribution of larvae of *Cyclothone* on ETP II was similar to that illustrated for equivalent ETP I. As on ETP I, the fewest occurrences (19 of 68 collections) were obtained between lat 10° and 20°N, and the Peruvian coastal waters were almost as poor. However, *Cyclothone* larvae were more abundant in the portion of ETP I that was

TABLE 18.—Frequency of occurrence and relative abundance of the kinds of gonostomatid larvae on EASTROPAC II, and for equivalent coverage on EASTROPAC I.

Gonostomatid genera or species	*Washington* 45,000 series		*Undaunted* 46.000 series		*Rockaway* 47.000 series		EASTROPAC II total (355 hauls)		Equivalent EASTROPAC I total (355 hauls)	
	No. positive hauls	No. larvae	No. positive hauls	No. larvae	No. positive hauls	No. larvae	No. positive hauls	No. larvae	No. positive hauls	No. larvae
Araiophos eastropas	1	35	0	0	0	0	1	35	0	0
Cyclothone spp.	64	358	54	331	69	283	187	972	190	1,106
Danaphos oculatus	1	1	0	0	0	0	1	1	0	0
Diplophos taenia	44	114	11	20	2	2	57	136	57	156
Gonostoma spp.	2	3	1	1	8	18	11	22	10	39
Ichthyococcus sp.	3	3	25	38	18	35	46	76	34	53
Maurolicus muelleri	4	11	24	551	19	211	47	773	43	264
Vinciguerria spp.	107	8,553	94	6,148	140	7,497	341	22,198	320	16,746
Woodsia sp.	0	0	2	3	2	2	4	5	3	3
Yarrella argenteola	0	0	1	1	17	32	18	33	1	1
Other gonostomatids	1	1	2	2	1	1	4	4	12	12
Total gonostomatids	108	9,079	94	7,095	140	8,081	342	24,255	333	18,380

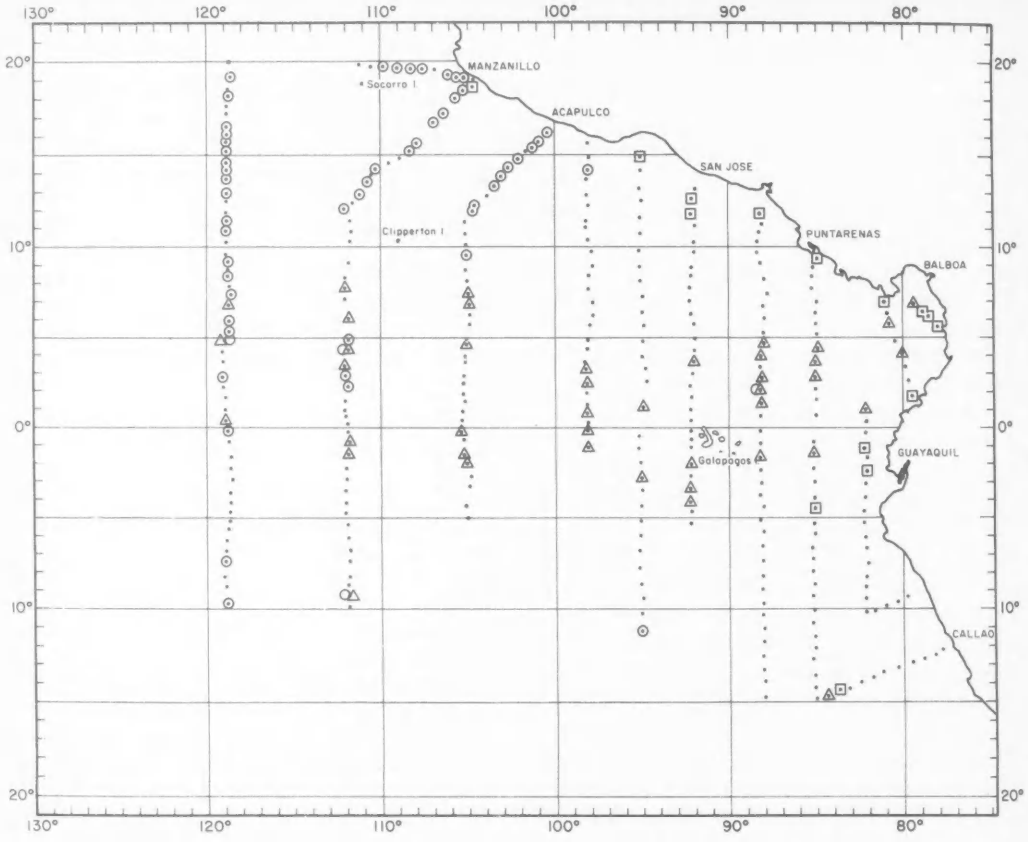

FIGURE 5.—Distribution of larvae of the gonostomatid, *Diplophos taenia* (open circle with dot), of the stomiatoid family, Astronesthidae (open triangle with dot), and of the synodontid genus, *Synodus* spp. (open square with dot). Small solid circles represent other stations occupied on ETP II.

not replicated on ETP II. In these collections *Cyclothone* larvae occurred in 111 of 127 collections, with an average abundance per collection of 8.7 larvae.

Danaphos oculatus (Garman)
(1 occurrence, 1 larva)

A single large larva was taken at the northern end of the *Washington* pattern at lat 19°16′N, long 118°56′W. Information obtained from California Current and NORPAC collections indicates that *Danaphos* is a temperate water species, occurring most commonly in collections obtained from the central water mass of the North Pacific in hauls which sampled to depths greater than 140 m.

Diplophos taenia (Günther)
(57 occurrences, 136 larvae)

Larvae of *Diplophos taenia* afford a striking example of similarities in distribution, frequency of occurrences, and relative abundance in the

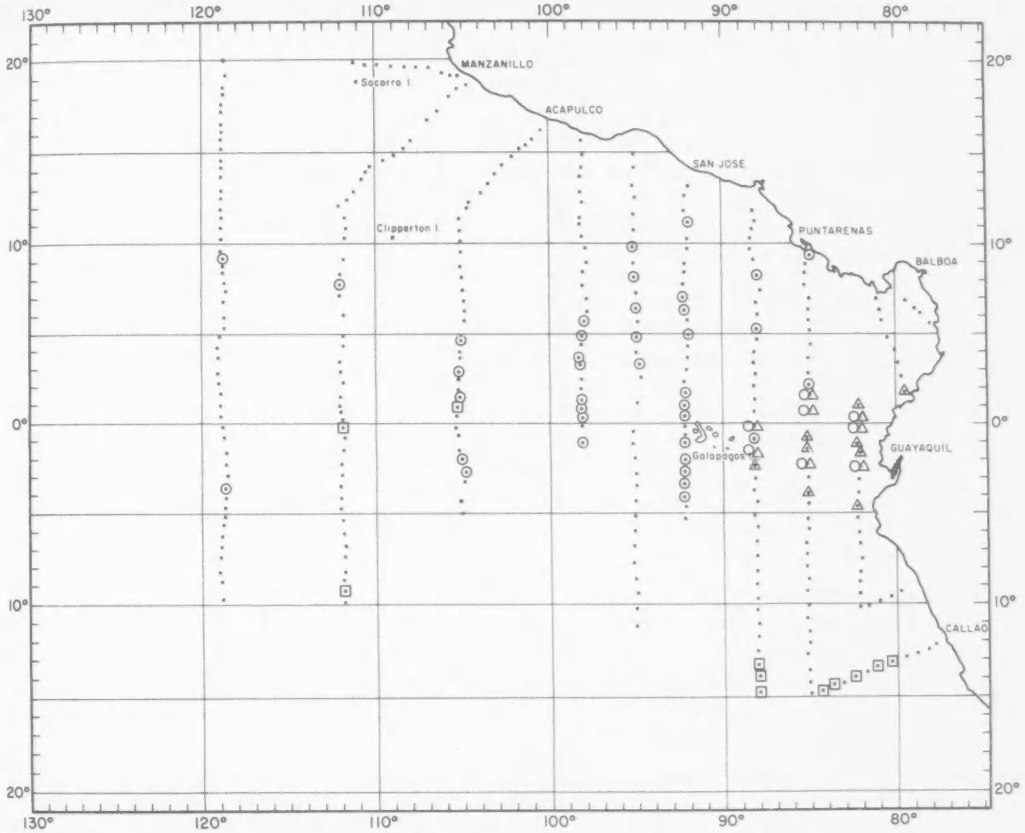

FIGURE 6.—Distribution of larvae of three kinds of gonostomatids. Records of occurrence of larvae of *Gonostoma* spp. shown as open square with dot, of *Ichthyococcus irregularis* as open circle with dot, and of *Yarrella argenteola* as open triangle with dot. Small solid circles represent other stations occupied on ETP II.

two EASTROPAC multivessel cruises. Larvae were obtained in 57 collections from both ETP II and equivalent ETP I; on both surveys the majority of larvae were taken to the north of lat 10°N, particularly on the coastward-oriented portion of the station line terminating off Acapulco, Mexico, and that terminating off Manzanillo, Mexico (Figure 5, and Ahlstrom, 1971, Figure 4). Larvae of this species were taken in moderate numbers, seldom more than 5 per haul; the average number per haul on ETP II was 0.38 larva versus 0.44 larva on equivalent ETP I.

Gonostoma sp.
(11 occurrences, 22 larvae)

At least two kinds of gonostomatid larvae have been referred to *Gonostoma*, the more common being larvae of *G. elongatum* Günther. The distribution of *Gonostoma* larvae on ETP II is shown in Figure 6; 8 of 11 occurrences were in a compact group in the southern, inshore portion of the ETP pattern (between lat 13° and 15°S, offshore to long 88°W).

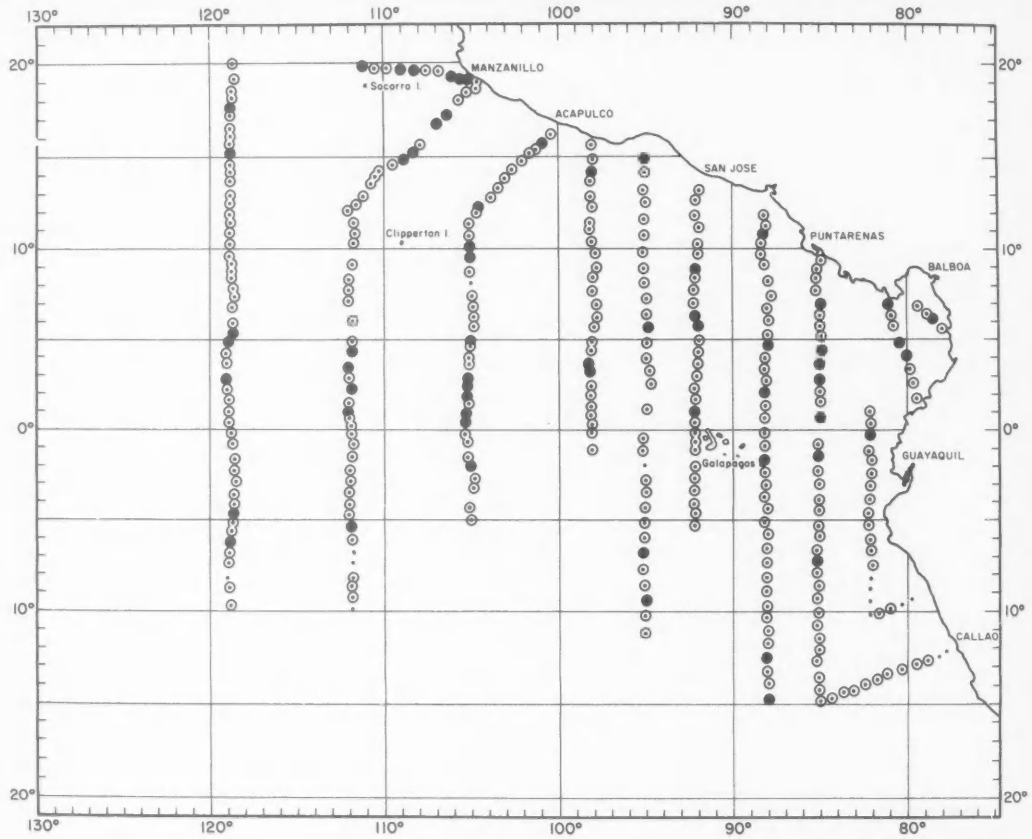

FIGURE 7.—Distribution of larvae of the gonostomatid, *Vinciguerria* spp. on ETP II. Collections of 1-100 larvae are shown as open circles with dot in center, collections of 101 or more larvae as large solid circles; negative hauls are shown as small solid circles.

***Ichthyococcus* sp.**
(46 occurrences, 76 larvae)

All *Ichthyococcus* larvae taken on ETP II were similar in appearance and have been referred to *I. irregularis* Rechnitzer and Böhlke. Although widely distributed (Figure 6), all larvae were obtained between lat 12°N and 4°S; only three collections of *Ichthyococcus* larvae were taken in the outer pattern occupied by *Washington*.

***Maurolicus muelleri* (Gmelin)**
(47 occurrences, 773 larvae)

Larvae of *M. muelleri* ranked third in abundance among gonostomatid larvae. As on ETP I, (Ahlstrom, 1971, Figure 4) larvae of this species were sampled in a rather narrow equatorial belt, and none were taken seaward of long 112°W. This again is a striking instance of the similarity in distribution of larvae on the two multivessel cruises. Although the incidence of occurrences of *Maurolicus* larvae was almost as

high in ETP I as in ETP II, 43 positive hauls as compared with 47, the average number of larvae per positive haul was much higher on ETP II—16.4 larvae versus 6.1 larvae.

Vinciguerria spp.
(341 occurrences, 22,198 larvae)

As in ETP I, larvae of *Vinciguerria* spp. ranked second in overall abundance, exceeded only by larvae of the myctophid, *Diogenichthys laternatus* (Garman). They were obtained throughout the EASTROPAC pattern, occurring in 96% of the collections (Figure 7). Average abundance of larvae per haul was about one-third greater than in ETP I: 62.5 versus 47.2 larvae.

Larvae of two species of *Vinciguerria* occur within the ETP II pattern, although most were those of *V. lucetia* Garman. As commented upon for ETP I, larvae of *V. nimbaria* (Jordan and Williamson) were taken principally in the South Pacific central water mass, to the south of about lat 5°S. On ETP II this distribution involves about 20 collections only.

Yarrella argenteola (Garman)
(18 occurrences, 33 larvae)

Larvae of *Y. argenteola* were taken in a limited area shoreward or immediately south of the Galapagos Islands between lat 2°N and 5°S (Figure 6). No metamorphosing specimens were observed, although larvae as large as 16 mm were represented in the collections. As noted in the introductory section, only one specimen of *Yarrella* was obtained on ETP I, in contrast to the 18 occurrences on ETP II. Adults of this species were recorded from within the area covered on ETP II by Morrow (1957b), Grey (1960), Bussing (1965), and Parin (1971).

7. STERNOPTYCHIDAE
(277 occurrences, 7,385 larvae)

As in ETP I, hatchetfish larvae ranked third in abundance. Although hatchetfish larvae contributed almost identical percentages of the total larvae in ETP II as in comparable ETP I (5.99% versus 5.98%), the average number of larvae per haul, 20.8 versus 13.9, reflected the greater relative abundance of larvae on ETP II. As noted for ETP I, hatchetfish larvae are more fragile than most kinds, and a portion of the larvae are too damaged to identify, except to family. Even so, identification to genus was made for most ETP II collections, and in these, larvae of *Sternoptyx* sp. contributed about 85% of the total and larvae of *Argyropelecus* (mostly *A. lychnus* Garman), the remainder. Baird (1971) in his revision of the family Sternoptychidae recognized three species of *Sternoptyx*, with *S. obscura* Garman the common species in the eastern tropical Pacific; however, he included one record of *S. diaphana* Hermann from within the area surveyed on ETP II.

8. ASTRONESTHIDAE
(42 occurrences, 74 larvae)

Astronesthid larvae were taken in about four times as many collections as on equivalent ETP I. Most larvae had an equatorial distribution between lat 8°N and 5°S; only two larvae occurred elsewhere (Figure 5). Three distinctive kinds of astronesthid larvae were taken.

9. CHAULIODONTIDAE
(56 occurrences, 207 larvae)

Although larvae of *Chauliodus* sp. were taken in a comparable number of hauls on ETP II and ETP I (56 versus 59 occurrences), more larvae were obtained on ETP II (207 versus 134 larvae). The majority of *Chauliodus* larvae on ETP II were taken in the inner half of the ETP pattern, below the equator—34 collections containing 165 specimens were obtained from this quadrant (Figure 8). In other parts of the ETP pattern somewhat fewer larvae were taken than on ETP I. As on ETP I, the majority of positive hauls contained 1 to 3 larvae (41 of 56 hauls); even so, a higher proportion of the hauls on ETP II contained somewhat larger numbers of *Chauliodus* larvae, i.e., 6 to 26 larvae per haul.

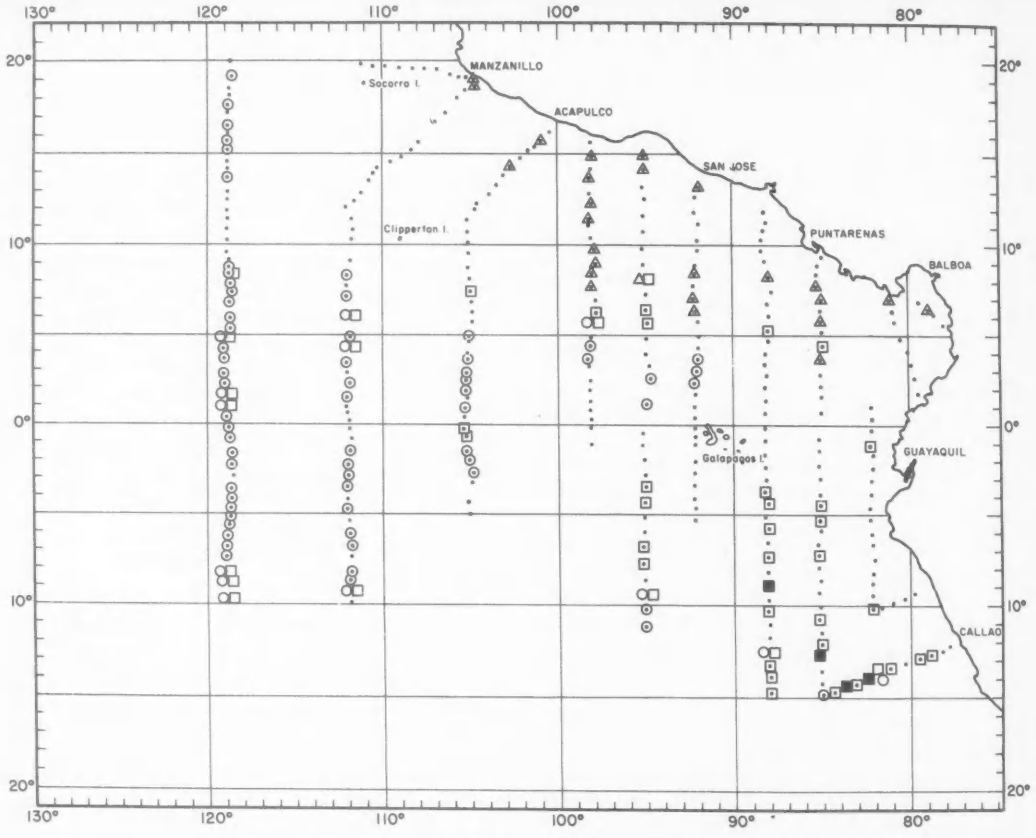

FIGURE 8.—Distribution of larvae of the stomiatoid genus *Chauliodus* sp. (open square with dot, 1-10 larvae, closed square, 11 or more larvae), of the myctophid, *Hygophum proximum* (open circle with dot), and of the bothid flatfish, *Bothus leopardinus* (open triangle with dot). Small solid circles represent other stations occupied on ETP II.

10. IDIACANTHIDAE
(181 occurrences, 795 larvae)

Larvae of *Idiacanthus* sp. were taken in over half of the plankton hauls made on ETP II; there was an increase in frequency of occurrence of *Idiacanthus* larvae as compared to equivalent ETP I, but not in actual abundance of larvae. Larvae of *Idiacanthus* were most abundant in the inshore quadrant to the north of the equator and least abundant in the offshore quadrant south of the equator (Figure 9). All larger collections of larvae (11 to 43 larvae per haul) were taken to the north of the equator, usually within 600 miles of the coast.

11. OTHER STOMIATOIDEI
(210 occurrences, 1,034 larvae)

Included under other Stomiatoidei in Table 9 are larvae of two stomiatoid families: Stomiatidae and Melanostomiatidae. In Appendix Table 1, the category "other Stomiatoidei" also includes the family Astronesthidae. In Appendix Table 3, counts are given for three principal

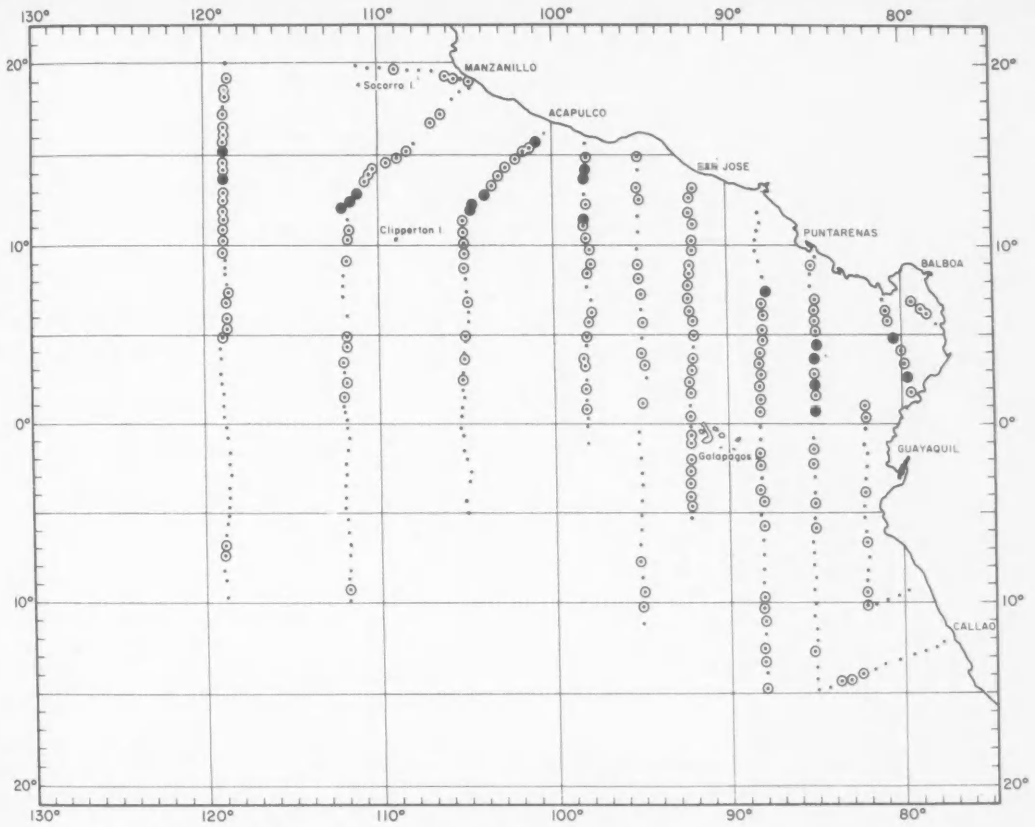

FIGURE 9.—Distribution of larvae of the stomiatoid genus *Idiacanthus* sp. on ETP II. Collections of 1-10 larvae are shown as open circles with dot in center, collections of 11 or more larvae as large solid circles; negative hauls are shown as small solid circles.

constituents: Astronesthidae, *Bathophilus filifer* (Garman), and *Stomias* sp.

Stomias larvae (43 occurrences, 177 larvae) were most abundant in the inner pattern. Larvae of three categories of Melanostomiatidae were identified to the genus or species level. The most common of these were larvae of *Bathophilus filifer* (Garman) (104 occurrences, 310 larvae). Larvae of *Eustomias* spp. (10 occurrences, 19 larvae) represented several species, whereas larvae of *Leptostomias* sp. (8 occurrences, 17 larvae) were those of a single species.

Approximately half of the stomiatoid larvae (140 occurrences, 511 larvae) were not identified below the subordinal level. These were mostly small or damaged specimens; some of the unidentified stomiatoid larvae possibly are those of Malacosteidae.

13. EVERMANNELLIDAE
(17 occurrences, 67 larvae)

The majority of evermannellid larvae were

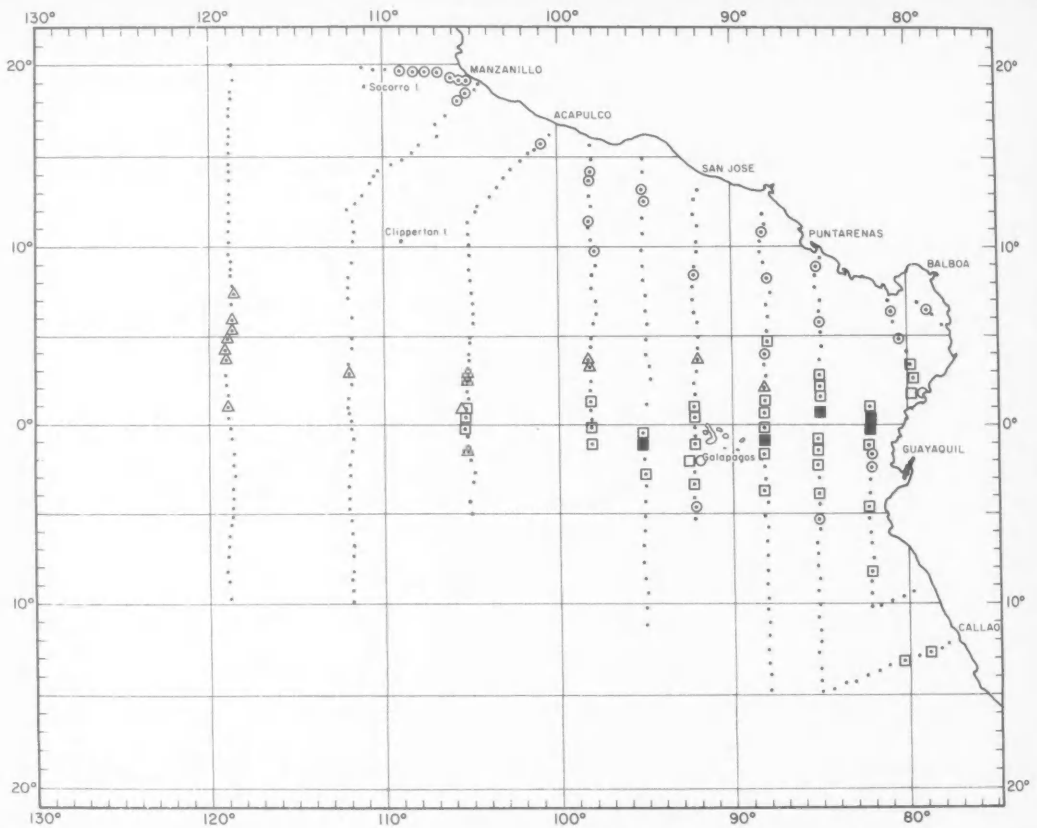

FIGURE 10.—Distribution of larvae of the myctophiform families Evermannellidae (open triangle with dot), and Scopelosauridae (open squares with dot, 1-25 larvae, closed squares, 26 or more larvae) and of the perciform family, Labridae (open circle with dot); negative hauls are shown as small solid circles.

taken on the outer line of stations along long 119°W; the remainder were taken in an equatorial band between lat 2°S and 4°N (Figure 10). This distribution is less widespread than that encountered on ETP I; however, 17 of the records of occurrence on ETP I were in the southern portion of the pattern not covered on ETP II.

14. MYCTOPHIDAE
(352 occurrences, 64,009 larvae)

Larvae of Myctophidae were more abundant on ETP II than on ETP I; the increase in abundance of myctophid larvae per haul in ETP II over ETP I was 1.63×. Much of the increase was due to the greater abundance of larvae of the dominant species, *Diogenichthys laternatus* (Garman), although a number of kinds of myctophid larvae were taken in somewhat greater abundance, and only a few kinds were taken in lesser numbers per haul (Table 19). To show changes in relative abundance of myctophid larvae between the two multivessel cruises, I have arranged the more common kinds in order of their relative abundance on ETP II as compared

TABLE 19.—Frequency of occurrence and relative abundance of the kinds of myctophid larvae on EASTROPAC II, and for equivalent coverage on EASTROPAC I.

Myctophid genera or species	*Washington* 45.000 series		*Undaunted* 46,000 series		*Rockaway* 47.000 series		EASTROPAC II total		Equivalent EASTROPAC I total	
	No. positive hauls	No. larvae	No. positive hauls	No. larvae	No. positive hauls	No. larvae	No. positive hauls	No. larvae	No. positive hauls	No. larvae
* *Benthosema panamense*	3	72	2	58	8	971	13	1,131	7	1,027
Benthosema suborbitale	1	1	1	1	0	0	2	2	7	7
Centrobranchus sp.	1	2	0	0	0	0	1	2	0	0
* *Ceratoscopelus townsendi* complex	12	365	0	0	1	24	13	389	37	349
* *Diaphus* spp.	73	938	53	1,113	51	382	177	2,433	168	1,931
* *Diogenichthys atlanticus*	1	1	0	0	3	9	4	10	6	7
* *Diogenichthys laternatus*	92	4,661	90	16,440	138	25,865	320	46,966	302	24,315
Diogenichthys sp.	0	0	0	0	2	4	2	4	0	0
* *Gonichthys tenuiculus*	15	25	27	99	64	169	106	293	88	226
* *Hygophum atratum*	38	335	10	46	18	140	66	521	85	529
* *Hygophum proximum*	54	499	15	75	8	50	77	624	55	448
* *Lampadena* spp.	7	8	3	6	0	0	10	14	15	27
Lampanyctus spp.	84	1,013	72	1,629	135	2,692	291	5,334	271	5,262
* *Lepidophanes pyrsobolus* complex	16	53	12	73	8	12	36	138	13	41
* *Lobianchia* sp.	5	8	2	2	3	5	10	15	10	26
* *Loweina laurae*	10	15	10	14	5	8	25	37	31	41
* *Myctophum aurolaternatum*	37	85	41	144	70	445	148	674	145	529
* *Myctophum aspersum*	16	118	10	62	0	0	26	180	(1)	(1)
* *Myctophum nitidulum*	25	300	43	274	66	717	134	1,291	(1)	(1)
* *Myctophum* other	11	27	6	13	0	0	17	40	117	1,042
* *Notolychnus valdiviae*	36	147	31	247	33	140	100	534	106	605
* *Notoscopelus resplendens*	14	28	29	198	35	156	78	382	54	231
* *Protomyctophum* sp.	5	7	12	22	8	15	25	44	33	74
* *Symbolophorus evermanni*	43	248	38	140	74	434	155	822	132	706
* *Triphoturus* spp.	23	40	27	132	94	652	144	824	111	356
Unidentified myctophid larvae	33	86	33	94	50	217	116	397	115	295
Disintegrated myctophid larvae	79	464	42	170	84	274	205	908	155	876
Total myctophid larvae	111	9,546	95	21,082	146	33,381	352	64,009	346	39,249

[1] Not separately tabulated.

to ETP I (comparable coverage, identical number of samples).

Genus or species of myctophid	*No. in ETP II* / *No. in ETP I*
Hygophum atratum-reinhardti	0.83
Notolynchus valdiviae	0.88
Symbolophorus evermanni	0.91
Lampanyctus spp.	1.01
Benthosema panamense	1.10
Ceratoscopelus townsendi-complex	1.11
Diaphus spp.	1.26
Myctophum aurolaternatum	1.27
Gonichthys tenuiculus	1.30
Hygophum proximum	1.39
Myctophum spp. (other than *M. aurolaternatum*)	1.45
Notoscopelus resplendens	1.66
Diogenichthys laternatus	1.93
Triphoturus spp.	2.31

Benthosema panamense (Tåning)
(13 occurrences, 1,131 larvae)

Although larvae of this species ranked fifth in abundance among myctophid larvae, they were collected in a relatively narrow coastal band, no wider than 200 miles (Figure 11). A similar pattern of inshore, clumped distribution was encountered on ETP I (Moser and Ahlstrom, 1970, Figure 45).

Benthosema suborbitale (Gilbert)
(2 occurrences, 2 larvae)

Only two specimens of the larvae of *Benthosema suborbitale* were taken on ETP II. Larvae of this species only recently have been positively identified. The larval series was initially established by Dr. H. G. Moser from *Dana* material. Larvae are strikingly similar to *Electrona*

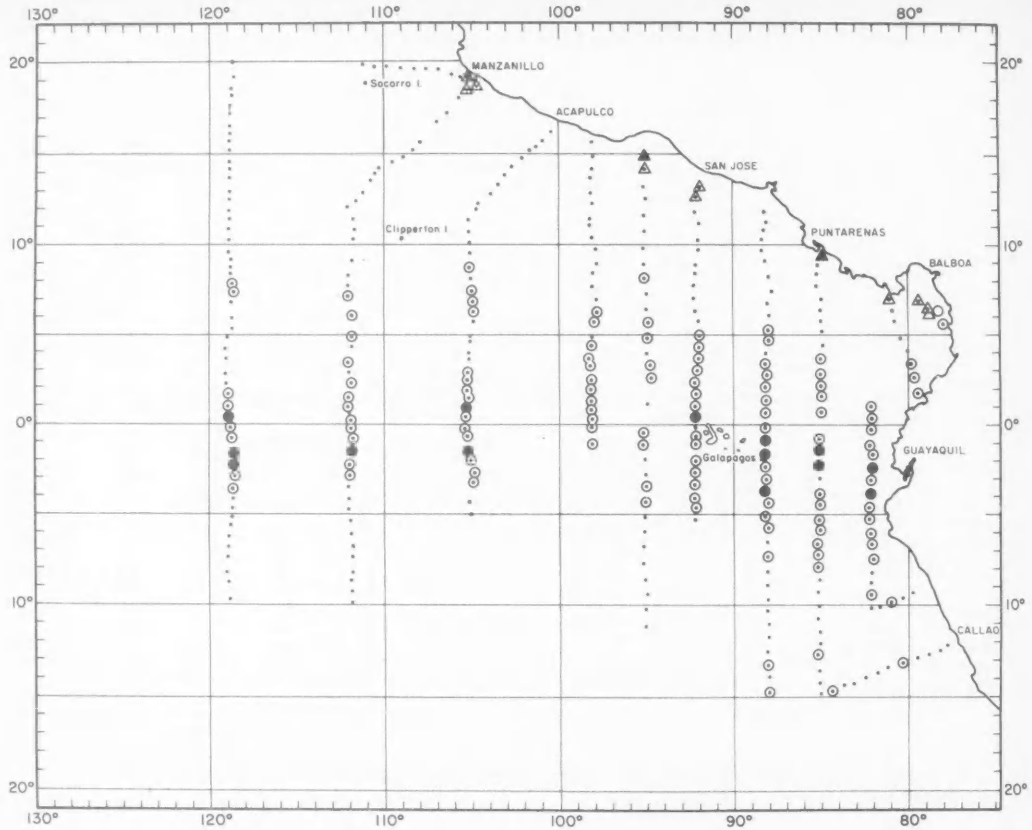

FIGURE 11.—Distribution of larvae of two species of myctophid lanternfishes. Records of occurrence of larvae of *Benthosema panamense* are shown as open triangles with dot for collections of 1-100 larvae, and as closed triangles for collections containing 101 or more larvae; records of occurrence of larvae of *Myctophum nitidulum* are shown as open circles with dot for collections of 1-25 larvae, and as large solid circles for collections containing 26 or more larvae; negative hauls are shown as small solid circles.

larvae, and earlier were confused with larvae of this genus. Most larvae included in *Electrona* sp. in the ETP I compilation were those of this species. The majority of occurrences of the larvae of this species on ETP I was in the southern, offshore portion of the ETP pattern, not covered on ETP II.

Ceratoscopelus townsendi-complex
(13 occurrences, 389 larvae)

Abbreviated coverage of the southern portion of the EASTROPAC pattern, with coverage limited to lat 10°S or 5°S on offshore lines, cut down markedly on the occurrences of larvae of *Ceratoscopelus*, as compared with ETP I: 13 occurrences as compared with 110. All occurrences but one of *Ceratoscopelus* larvae on ETP II were obtained in the outer pattern, occupied by *Washington*: 2 at the two northernmost stations along long 119°W, and 10 in the southern portion of the pattern between lat 6° and 10°S along long 119° and 112°W (Figure 12). Both clus-

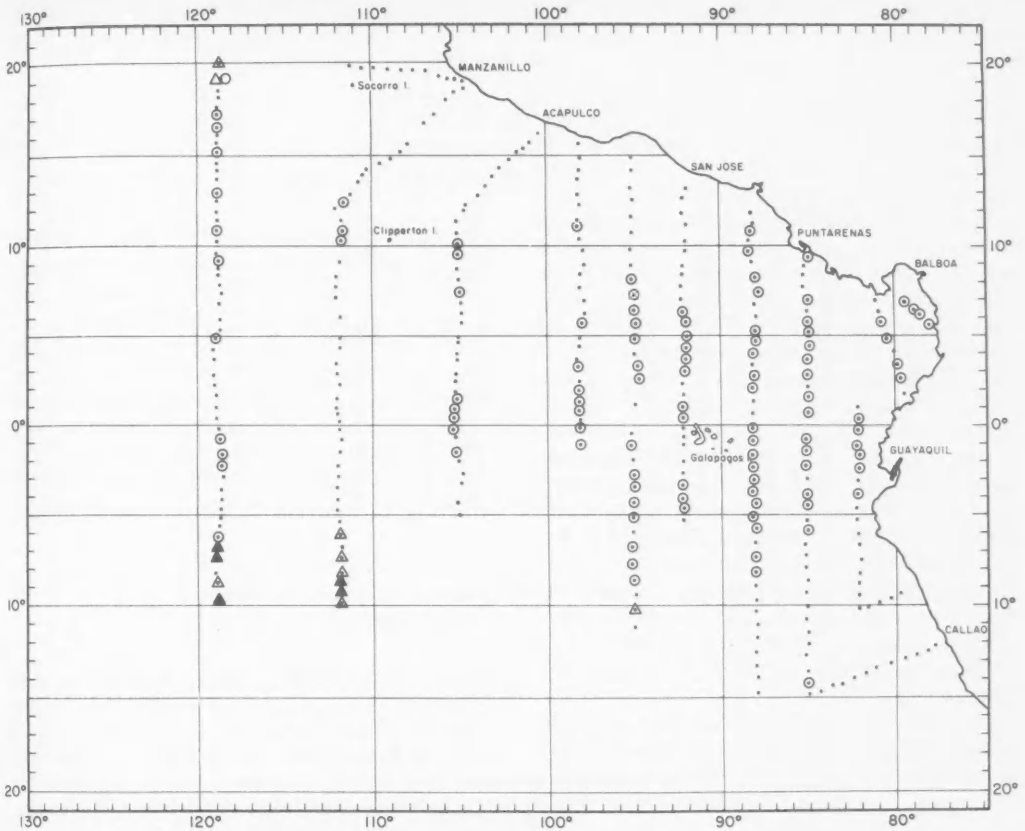

FIGURE 12.—Distribution of larvae of two species of myctophid lanternfishes. Records of occurrence of larvae of *Ceratoscopelus townsendi*-complex are shown as open triangles with dot for collections of 1-25 larvae and as closed triangles for collections of 26 or more larvae; records of occurrence of larvae of *Gonichthys tenuiculus* are shown as open circles with dot; negative hauls are shown as small solid circles.

ters of larvae occurred in the central water masses of the North and South Pacific.

Diaphus spp.
(177 occurrences, 2,433 larvae)

Larvae of *Diaphus* rank third in abundance among myctophid genera, exceeded only by *Diogenichthys* and *Lampanyctus*. Although *Diaphus* larvae were taken in half the collections made on ETP II, occurrences and nonoccurrences tended to be clustered. Almost two-thirds of *Diaphus* larvae were obtained to the north of lat 10°N on the four outer station lines; these were predominantly larvae of *D. pacificus* Parr. The largest area of nonoccurrence was off Peru, between lat 5° and 15°S; here *Diaphus* larvae were absent from 42 consecutive stations, 47.081 to 47.197. Larvae of the subgenus *Diaphus*, which are quite distinctive, made up about 10% of the total.

Juveniles and adult *Diaphus*, separated from micronekton hauls made on ETP I, have been identified, with the cooperation of Robert Wisner of Scripps Institution of Oceanography: 15 species were represented in the collection made by *Argo*, *David Starr Jordan*, and *Alaminos* on ETP I. *D. pacificus* was, by far, the most abundant species, occurring in more collections and in larger numbers than other species of *Diaphus*. This species occurs in a broad coastal belt, 600 to 800 miles wide, from lat 20°N to the vicinity of the equator. Six species were taken offshore, between lat 5° and 20°S, in the South Pacific central water mass, including *D. rolfbolini* Wisner, *D. brachycephalus* Tåning, *D. fragilis* Tåning, *D. jenseni* Tåning, *D. schmidt* Tåning, and *D. splendidus* (Brauer). Five species were taken in an offshore equatorial belt, between lat 10°N and 5°S, including *D. garmani* Gilbert, *D. malayanus* Weber, *D. termophilus* Tåning, *D. lucidus* Goode and Bean, and *D. lutkeni* Brauer, the latter showing some admixture with central water mass species. Species belonging to subgenus *Diaphus*, tentatively identified by Wisner as *D. longleyi* Fowler and *D. mollis-nanus* complex had quite widespread distributions.

Now that the species composition of adult *Diaphus* has been clarified, life history series can be determined for the more common kinds.

Diogenichthys laternatus (Garman)
(320 occurrences, 46,966 larvae)

Larvae of *D. laternatus* were outstandingly abundant, making up 38.1% of the total fish larvae obtained on ETP II. Almost twice as many *D. laternatus* larvae were taken in equivalent coverage of the EASTROPAC region on ETP II as on ETP I; 46,966 versus 24,315 larvae. The number of collections that contained *D. laternatus* larvae, however, was not much different: 302 of 355 in ETP I as compared with 320 of 355 in ETP II. Almost one collection in three from ETP II contained over 100 *D. laternatus* larvae, and 19 collections contained over 500 larvae. Of these larger collections, 13 of 19 were taken between lat 5° and 10°N. As on ETP I, larvae of *D. laternatus* were *not* taken in collections made within the central water mass of the South Pacific (Figure 13).

Diogenichthys atlanticus (Tåning)
(4 occurrences, 10 larvae)

Larvae of this species were taken more frequently on ETP I (29 occurrences, 92 larvae); however, all but six of these occurrences were in the portion of the ETP I pattern that was not covered on ETP II. The four records on ETP II were taken between lat 9° and 15°S, with two occurrences in the transitional waters of the Humboldt Current and only one occurrence offshore in the central water mass. Larvae of this species were commonly taken on MARCHILE VI off Chile (12 occurrences, 100 + larvae).

Gonichthys tenuiculus (Garman)
(106 occurrences, 293 larvae)

Larvae of *Gonichthys* had rather similar distributions and frequency of occurrences in the two multivessel EASTROPAC surveys. The majority of larvae were obtained in the inner pattern occupied by *Rockaway*, with highest frequency of occurrences in an equatorial belt between lat 5°N and 5°S (Figure 12).

Hygophum atratum (Garman)
(66 occurrences, 521 larvae)

The less extensive coverage on ETP II eliminated the area in which *H. reinhardti* (Lütken) larvae were taken on ETP I, and only larvae of *H. atratum* were observed in ETP II collections. Larvae of *H. atratum* were spottily distributed, occurring mostly in three clusters of stations: 1) between lat 15° and 20°N in the *Washington* pattern, 2) between lat 10° to 15°S in the *Rockaway* pattern, and 3) an equatorial band between lat 5°N and 5°S along long 119°, 112°, and 105°W.

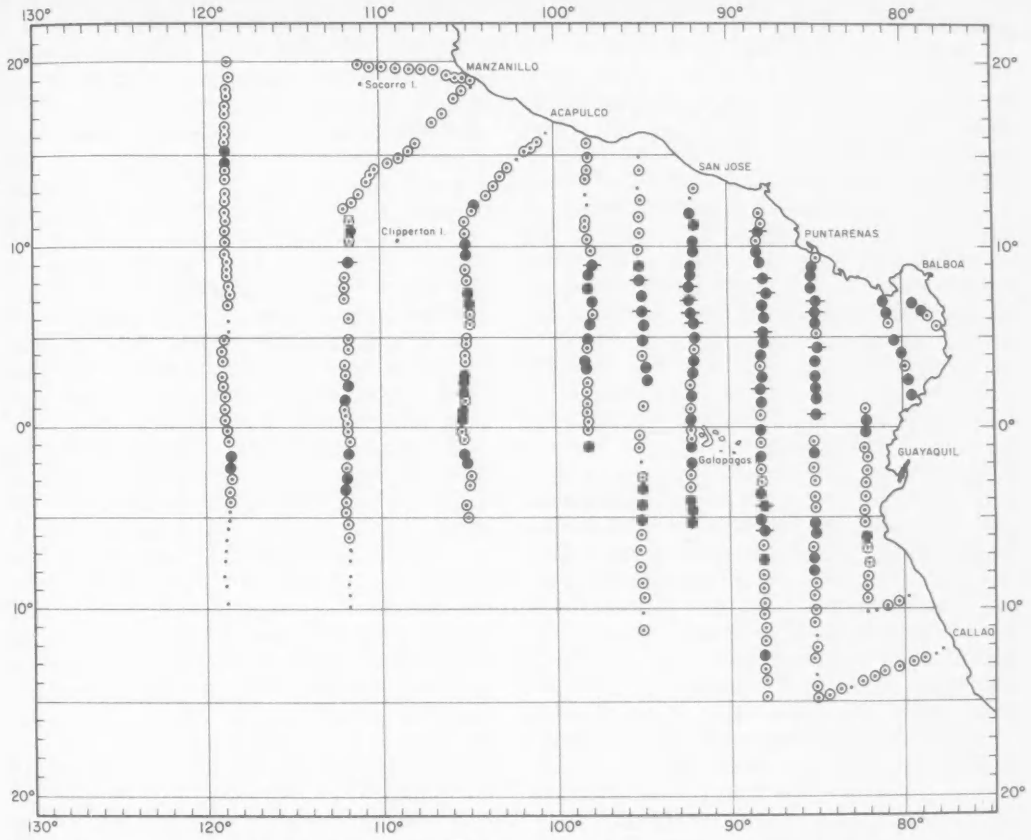

FIGURE 13.—Distribution of larvae of the myctophid *Diogenichthys laternatus* on ETP II. Three orders of abundance are shown. Open circles with dot represent counts of 1-100 larvae, large solid circles represent counts of 101-500 larvae, and large solid circles with bisecting line represent counts of 501 or more larvae; negative hauls are shown as small solid circles.

Hygophum proximum (Becker)
(77 occurrences, 624 larvae)

The distribution of larvae of *H. proximum* again is illustrated (Figure 8) to show the marked similarity in distribution to ETP I (Ahlstrom, 1971, Figure 10). Larvae of this species were decidedly more abundant in the offshore pattern occupied by *Washington* (55 occurrences, 499 larvae). As noted earlier, larvae of *H. proximum* were taken in somewhat greater abundance in ETP II as compared to equivalent ETP I (1.39×). Fully half of the occurrences and specimens of *H. proximum* larvae on ETP I was in the unreplicated portion of ETP I coverage, i.e., on the offshore line of stations along long 126°W and in the offshore southern portion of the pattern. There were three occurrences of larvae on ETP II in the southern part of the *Rockaway* pattern in transitional waters of the Humboldt Current; larvae were not obtained from this area on ETP I.

Lampadena sp.
(10 occurrences, 14 larvae)

Larvae of *Lamapadena* sp. were taken on the three offshore lines in two groups—one occurring between lat 3° and 8°N and the other in the central water mass of the South Pacific between lat 7° and 10°S. A similar distributional pattern was obtained on ETP I; however, the more extensive coverage of the South Pacific central water mass on the earlier survey provided better distributional information for the southern component.

Lampanyctus spp.
(291 occurrences, 5,334 larvae)

Lampanyctus larvae rank second in abundance and in frequency of occurrence among the myctophid genera represented in the eastern tropical Pacific. *Lampanyctus* larvae were most abundant between lat 5°N and 5°S and least common between lat 10° and 20°N. The six collections of *Lampanyctus* larvae that contained over 100 specimens per collection were taken between the equator and lat 5°N. Three kinds of *Lampanyctus* larvae dominated over most of the EASTROPAC pattern. Although identification to the species level are tentative as yet, these three kinds of larvae are almost certainly those of *L. idostigma* Parr, *L. omostigma Gilbert*, and *L. parvicauda* (Parr)—three widespread tropical species of *Lampanyctus*. A quite different assemblage of *Lampanyctus* larvae was taken in the moderate number of stations occupied in the South Pacific central water mass.

Lepidophanes pyrsobolus complex
(36 occurrences, 138 larvae)

An examination of the juvenile and adult specimens of *Lepidophanes* collected on ETP I has shown that two closely related species are present—one with a very restricted distribution and the other with a widespread distribution. Nafpaktitis and Nafpaktitis (1969) found three species of *Lepidophanes* from the Indian Ocean with common characteristics attributed to *L. pyrsobolus*. These workers considered Alcock's poorly described *L. pyrsobolus* as unidentifiable. Instead they identified their material with *L. photothorax* (Parr), *L. longipes* (Brauer), and *L. indicus* Nafpaktitis and Nafpaktitis. *L. photothorax* was taken in four ETP I collections between lat 15° and 20°S in the offshore pattern occupied by *Argo*. The specimens from the eastern Pacific agree closely with the description and illustration of this species in Nafpaktitis and Nafpaktitis (1969). These workers gave 7 + 4 as the usual combination of AO photophores on specimens from Indian Ocean material. In the EASTROPAC area all specimens examined had 6 + 4 AO photophores.

The widely distributed species in the EASTROPAC area is either *L. longipes* (Brauer) or a species closely related to *L. longipes*. The eastern Pacific form has similar luminous patches to those described for *L. longipes* from the Indian Ocean except for the luminous tissue on the head of males and the size of the infracaudal gland on some larger specimens. Luminous patches developed on the head were restricted to a single wide pair of luminous patches. On some larger specimens the infracaudal gland began under the last AO photophore and was conspicuously larger than those observed by Nafpaktitis and Nafpaktitis (1969) on Indian Ocean material. AO photophores were usually 5 + 4; gill raker counts were 5 + 1 + 11 to 13.

Two kinds of *Lepidophanes* have been observed in the EASTROPAC area, although only one kind was taken commonly. Larvae of the latter have been assigned to *L. longipes* (?).

Lobianchia spp.
(10 occurrences, 15 larvae)

Larvae of *Lobianchia*, although uncommon in the eastern tropical Pacific, have a fairly widespread distribution in two separated areas: 1) in an equatorial belt between lat 3°S and 6°N (8 occurrences) and 2) in the transitional waters of the Humboldt Current. In the latter area, two occurrences were recorded at about lat 12°

to 13°S along long 88°W, and three additional records were obtained at MARCHILE VI stations (not included in above totals). At least two species, *L. gemellari* (Cocco) and *L. dumerili* (Bleeker), and perhaps a third, are involved.

Loweina laurae (Wisner)
(25 occurrences, 37 larvae)

Wisner (1971) has separated the eastern Pacific species of *Loweina* from *L. rara* (Lütken). Although the two species are basically quite similar, Wisner points out that *L. laurae* has a somewhat longer head, 27.3 to 30.7% of SL versus about 25.7%, and a somewhat larger eye, averaging about 8% of SL versus about 6%. Wisner gave the distribution of *L. laurae* in the eastern Pacific as between lat 30°N and 30°S and westerly to long 150°W.

Of the 25 occurrences of larvae of *L. laurae* on ETP II, all but one occurred in a broad equatorial band between lat 7°N and 6°S (Figure 14). The isolated record was on the southernmost line of stations oriented normal to the coast occupied by *Rockaway*. This distribution is similar to that illustrated for ETP I (Moser and Ahlstrom, 1970, Figure 51). In equivalent coverage on ETP I, 31 stations yielded 41 larvae. It should be noted that larvae of *Loweina* from EASTROPAC appear to be identical with those identified as *L. rara* from other oceans; hence larval evidence does not support the separation of the eastern Pacific form as a separate species.

Myctophum spp.
(217 occurrences, 2,185 larvae)

Larvae of the genus *Myctophum* ranked fourth in abundance and third in frequency of occurrence. Larvae of *M. aurolaternatum* Garman (148 occurrences, 674 larvae) were taken more frequently but in lesser amounts than larvae of *M. nitidulum*-complex (134 occurrences, 1,291 larvae). Larvae of *M. aurolaternatum* were taken in all parts of the EASTROPAC pattern, but in largest numbers between the equator and lat 5°N. Most larvae of *M. nitidulum*-complex were taken in a broad equatorial band between lat 8°N and 5°S (Figure 11). The distribution, however, had a southerly extension to the bottom of the pattern in the area of the Humboldt Current. Larvae of *M. asperum* Richardson (26 occurrences, 180 larvae) were taken in an offshore equatorial tongue, extending seaward from long 98°W to its widest extent (lat 2°S to 7°N) along long 119°W (Figure 3). The remainder of *Myctophum* larvae (17 occurrences, 40 larvae) belong to two and possibly three species. One group of these occurred in the offshore equatorial tongue, along with larvae of *M. asperum;* the other group occurred between lat 7° and 10°S in the offshore *Washington* pattern. The latter group includes larvae of both *M. lychnobium* Bolin and *M. brachygnathos* (Bleeker).

Only larvae of *M. aurolaternatum* were separately tabulated for equivalent ETP I coverage (145 occurrences, 529 larvae). Both the distribution of *M. aurolaternatum* larvae and their frequency of occurrence were similar for the two multivessel surveys, although abundance was moderately greater on ETP II, 1.9 versus 1.5 larvae per haul. This pattern of greater abundance on ETP II also held for the remainder of the larvae of *Myctophum*, 4.3 versus 2.9 larvae per haul.

Notolychnus valdiviae (Brauer)
(100 occurrences, 534 larvae)

Larvae of the wide-ranging oceanic species are seldom taken closer to shore than 200 miles. On ETP II, the majority of records were from an equatorial tongue that extended between lat 10°S and 10°N in the offshore *Washington* pattern, but shoreward of this (long 105° to 85°W) the distribution narrowed to between lat 2°S and 8°N, with the majority of occurrences between lat 2° and 6°N. A second group of larvae were sampled in the southern portion of the *Rockaway* pattern between lat 9° and 15°S. Only two occurrences of *Notolychnus* larvae were noted in 85 stations occupied by all vessels between lat 20° and 10°N. Distribution of *Notolychnus*

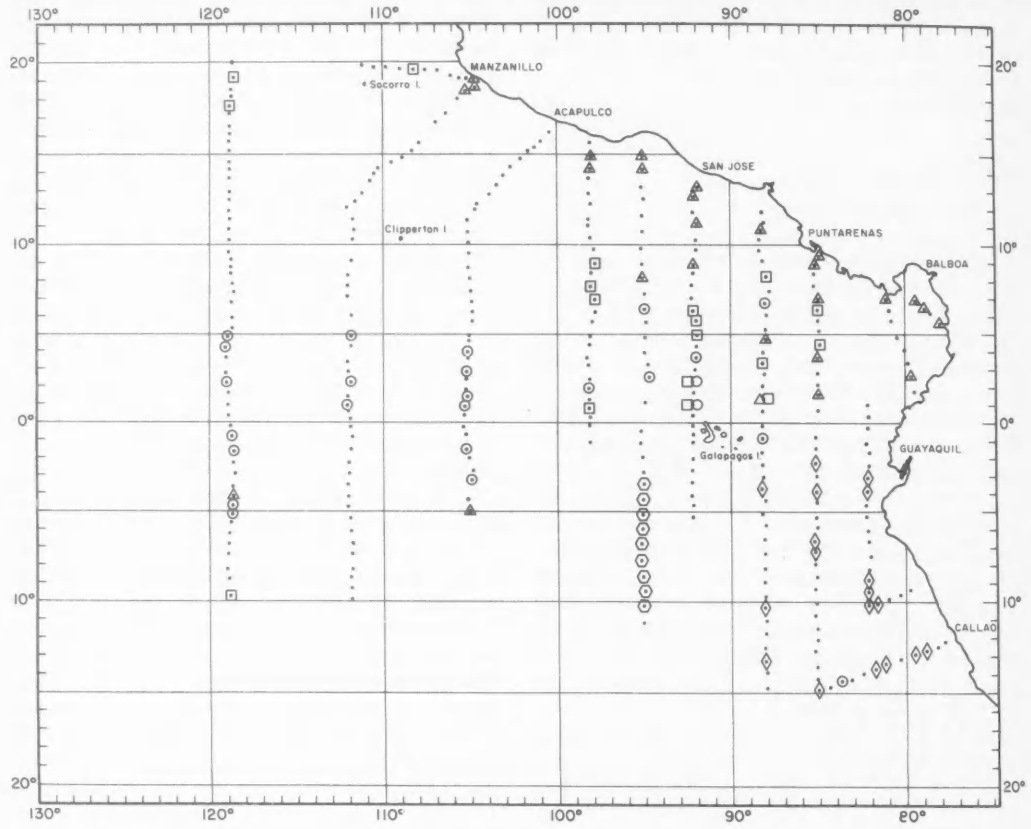

FIGURE 14.—Distribution of larvae of the myctophid, *Loweina laurae* (open circle with dot), of the scomberesocids, *Scomberesox saurus* (open diamond with dot), and *Cololabis adocetus* (open hexagon with dot) and of the anguilliform families Congridae (open triangle with dot) and Nemichthyidae (open square with dot); negative hauls are shown as small solid circles.

larvae was illustrated for ETP I coverage (Ahlstrom, 1971, Figure 11). In the portion of ETP I pattern also covered on ETP II, frequency of occurrence and distribution of *Notolychnus* larvae were quite similar: 1.7 versus 1.5 larvae.

Notoscopelus resplendens (Richardson)
(78 occurrences, 382 larvae)

As on ETP I, most larvae of *N. resplendens* were taken in an equatorial belt, between lat 5°N and 5°S (65 occurrences, 364 larvae). A second center of occurrence was at the southern portion of the *Rockaway* pattern between lat 9° and 15°S. Except that the distribution of the main group of *Notoscopelus* larvae is more definitely centered on the equator, the distribution of larvae of *Notoscopelus* and *Notolychnus* are quite similar. No larvae of *Notoscopelus* were taken north of lat 6°N. Moderately more larvae of *Notoscopelus* were taken on ETP II, 1.1 versus 0.7 larvae per haul.

Protomyctophum sp.
(25 occurrences, 44 larvae)

For most kinds of myctophids, the distributional patterns of larvae are so similar in the two multivessel EASTROPAC survey cruises that distributional information from ETP II merely reinforced that obtained on ETP I. Distribution of *Protomyctophum* larvae affords another example of this. All but two of the occurrences lie between lat 10°N and 5°S, the zone in which all *Protomyctophum* larvae were obtained on ETP I. As noted in Ahlstrom (1971), the larvae were all of a kind, belonging to a perhaps undescribed species of *Protomyctophum*, subgenus *Hierops*. Wisner (1971) described two new species of *Protomyctophum*, subgenus *Hierops* from the eastern Pacific: *P. chilensis* from off Chile about lat 33°S and *P. beckeri* from the vicinity of the Hawaiian Islands. It is not known as yet whether the form from EASTROPAC is referable to either of these.

Symbolophorus evermanni (Gilbert)
(155 occurrences, 822 larvae)

Larvae of *Symbolophorus* were absent from a wide coastal strip off Mexico and a narrower coastal strip off Peru, but were taken at most stations in the remainder of the ETP II pattern. The distribution was rather similar to that illustrated for ETP I (Ahlstrom, 1971, Figure 12); the frequency of occurrence was slightly lower on equivalent ETP I (37% positive hauls versus 44%), but the average abundance per haul was slightly higher (2.6 versus 2.3 larvae). However, in the ETP I stations without counterparts in ETP II, frequency of occurrence was higher than in the remainder of the ETP I pattern (63% versus 37%) and average abundance per haul was higher (4.5 versus 2.6 larvae).

Triphoturus spp.
(144 occurrences, 824 larvae)

Larvae of *Triphoturus oculeus* (Garman) were taken in most hauls made between lat 5°N and 15°S off Ecuador and Peru and offshore to the vicinity of the Galapagos Islands. Larvae of this species, which appear to be more exclusively restricted to the transition waters of the Humboldt Current than are those of other myctophids sampled in the EASTROPAC pattern, also may exhibit the most marked seasonal change in relative abundance. Other *Triphoturus* larvae, sampled mostly offshore, were taken in slightly lesser abundance than on ETP I.

16. PARALEPIDIDAE
(247 occurrences, 2,535 larvae)

Larvae of Paralepididae ranked sixth in abundance and contributed over 2% of the total. Larvae were taken throughout the ETP II pattern, but most commonly in an equatorial band between lat 5°N and 5°S; all collections of larvae exceeding 25 larvae per haul were obtained from this band. Fewest larvae were taken in the southern portion of the inner pattern, below about lat 7°S. Because of limited coverage of the South Pacific central water mass on ETP II, no material was obtained of *Sudix atrox* Rofen (see Ahlstrom, 1971, Figure 7 for distribution of larvae of this species on ETP I). A detailed study of the species composition of the paralepidid material from EASTROPAC surveys has not been made.

17. SCOPELARCHIDAE
(134 occurrences, 298 larvae)

Larvae of Scopelarchidae were taken throughout the area surveyed on ETP II. As noted for ETP I (Ahlstrom, 1971, p. 32-33), larvae of five or six kinds of scopelarchids were obtained, usually in small numbers per haul. On ETP II, only 6 of 133 positive hauls contained over 5 larvae (6 to 12 larvae), and over 80% of the hauls contained 1 to 3 larvae per haul.

18. SCOPELOSAURIDAE
(40 occurrences, 390 larvae)

Larvae of Scopelosauridae were taken in more

hauls and in much larger numbers than on equivalent ETP I (6 occurrences, 13 larvae). As shown in Figure 10, most occurrences were in an equatorial band between lat 5°N and 5°S and offshore to long 105°W; the five hauls containing 25 or more larvae were obtained within 2° of the equator. Only one kind of *Scopelosaurus* larva was obtained on ETP II. Larvae of *Scopelosaurus* superficially resemble paralepidid larvae—both have elongate larvae with a short gut that increases in relative length in older larvae. However, *Scopelosaurus* larvae differ in several significant ways from paralepidid larvae. *Scopelosaurus* larvae never develop patches of pigment above the intestinal tract, whereas these patches are a striking feature of paralepidid larvae; the eyes of *Scopelosaurus* larvae are narrowed, whereas they are round in most paralepidid larvae; also the intestinal tract does not increase in relative length nearly as much in older stage *Scopelosaurus* larvae as in paralepidid larvae.

19. SYNODONTIDAE
(14 occurrences, 60 larvae)

Larvae of *Synodus* spp. occurred in a coastal band along the extent of the ETP II pattern (Figure 5). Six species of *Synodus* are known to occur in the eastern Pacific. Several kinds of *Synodus* larvae were taken in the EASTROPAC collections, mostly small specimens. Until more older-stage larvae are obtained, it will not be possible to work out life history series.

21. ANGUILLIFORMES (EEL LEPTOCEPHALI)
(81 occurrences, 151 larvae)

Eel leptocephali, although conspicuous members of the larval fish fauna, are not common in the EASTROPAC pattern: they contributed only 0.12% of the total ETP II larvae. Leptocephali of seven families of true eels of the order Anguilliformes, suborder Anguilloidei, were identified from the micronekton net collections of ETP II. The micronekton net collections from ETP I contributed three times as many leptocephali as the regular net hauls; a total of 10 families was represented in the combined ETP I collections, including the 7 discussed below and in addition Derichthyidae, Muraenesocidae, and Nettastomidae. The record of occurrence and counts by family of eel leptocephali on all positive stations is contained in Appendix Table 5, and summarized in Table 20. The distributions of larvae of the seven families taken in ETP II collections are shown in Figures 14 and 15.

Congridae
(28 occurrences, 42 larvae)

This family ranked first in frequency of occurrence among eel leptocephali and second in relative abundance. Most congrid larvae were identifiable to genus. The breakdown was as follows: *Ariosoma* sp. (5 occurrences, 8 larvae), *Bathyconger* sp. (3 occurrences, 4 larvae), *Gnathopis* sp. (1 occurrence, 1 larva), *Hildebrandia* (10 occurrences, 18 larvae), *Paraconger* (4 occurrences, 5 larvae), and genus uncertain (6 occurrences, 6 larvae). All but two occurrences were from north of the equator, and most specimens were taken in a broad coastal band. However, offshore oceanic occurrences of congrid leptocephali were more frequent on ETP I than on ETP II.

Moringuidae
(3 occurrences, 3 larvae)

One occurrence of leptocephali of the moringuid genus *Neoconger* was off Manzanillo, Mexico, the other two near Panama Bay.

Muraenidae
(5 occurrences, 6 larvae)

Although adults of Muraenidae are known to have a wide distribution in the eastern Pacific, the few leptocephali taken on ETP II were confined to a narrow tongue extending offshore between lat 7° and 10°N in the northeast quadrant.

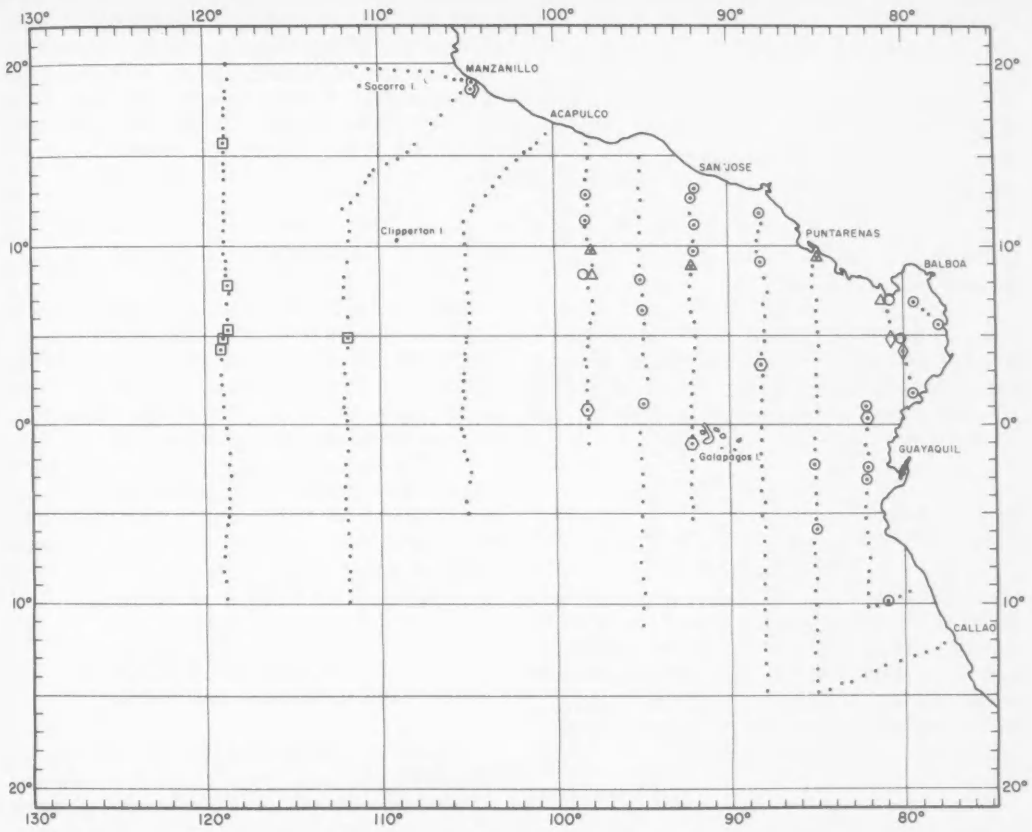

FIGURE 15.—Distribution of eel leptocephali of the anguilliform families: Moringuidae (open diamond with dot), Muraenidae (open triangle with dot), Opichthidae (open circle with dot), Serrivomeridae (open square with dot), and Xenocongridae (open hexagon with dot); negative hauls are shown as small solid circles.

TABLE 20.—Familial composition of eel leptocephali taken on the second multivessel EASTROPAC survey, summarized by vessel pattern.

Family	*Washington* 45.000 series		*Undaunted* 46.000 series		*Rockaway* 47.000 series		Total EASTROPAC II	
	No. positive hauls	No. larvae	No. positive hauls	No. larvae	No. positive hauls	No. larvae	No. positive hauls	No. larvae
Congridae	3	6	9	11	16	25	28	42
Moringuidae	1	1	0	0	2	2	3	3
Muraenidae	0	0	3	3	2	3	5	6
Nemichthyidae	4	5	9	9	6	7	19	21
Ophichthidae	2	8	7	12	17	29	26	49
Serrivomeridae	6	8	0	0	0	0	6	8
Xenocongridae	0	0	2	2	2	2	4	4
Family unknown	4	5	4	5	5	8	13	18
Total	16	33	30	42	35	76	81	151

Nemichthyidae
(19 occurrences, 21 larvae)

Although eels of this family are widely distributed in offshore oceanic waters, most occurrences of leptocephali (14 of 19) were in the northeast quadrant, between lat 0° and 10°N.

Ophichthidae
(26 occurrences, 49 larvae)

Ophichthid leptocephali were taken in a broad coastal band between Manzanillo, Mexico, and Central Peru (lat 10°S). They ranked first in relative abundance among eel leptocephali and second in frequency of occurrence.

Serrivomeridae
(6 occurrences, 8 larvae)

Most occurrences of serrivomerid leptocephali (5 of 6) were on the outer line of the ETP II pattern, along long 119°W, and the remaining occurrence was along long 112°W. In contrast to nemichthyid leptocephali which may grow to 300 or 400 mm long, leptocephali of Serrivomeridae rarely exceed about 60 mm.

Xenocongridae
(4 occurrences, 4 larvae)

The few occurrences of leptocephali of *Chlopsis*, the sole representative of this family, were within 4° of the equator.

22. MELAMPHAIDAE
(284 occurrences, 1,365 larvae)

Larvae of Melamphaidae ranked fourth in frequency of occurrence, eighth in relative abundance. Larvae were distributed throughout the ETP II pattern (Figure 16) and occurred in 80% of the collections. Most collections contained only moderate numbers of larvae—the average number of larvae per positive haul was only 4 to 8. The majority of hauls containing larger numbers of larvae (11 or more per haul) were taken within 5° of the equator (Figure 16). Melamphaid larvae were represented by four genera: *Melamphaes*, *Scopelogadus*, *Scopeloberyx*, and *Poromitra*.

23. TRACHICHTHYIDAE
(11 occurrences, 70 larvae)

The big-headed larvae of a representative of this family were taken at 11 stations on the two inner lines of the *Rockaway* pattern, between about lat 2° to 8°S (Appendix Table 3). They appear to be larvae of *Trachichthys mento* Garman, initially described from the Gulf of Panama. Bussing (1965) supplemented Garman's description, utilizing 53 specimens (55 to 104 mm) collected at *Eltanin* Station 34 at lat 07°45′ to 07°48′S, long 81°23′W. Parin (1971) also obtained material of this species in the eastern tropical Pacific from off South America.

25. BREGMACEROTIDAE
(160 occurrences, 3,062 larvae)

Larvae of Bregmacerotidae ranked fifth in abundance and contributed 2.5% of fish larvae on ETP II. The majority of larvae was taken to the north of the equator, with three inshore collections contributing over 70% of the total. These collections of 927, 753, and 511 larvae were exclusively *Bregmaceros bathymaster* Jordan. Larvae of this species were distributed in a broad coastal band in the northern half of the EASTROPAC pattern. As noted in the ETP I report, larvae of five species of *Bregmaceros* are distributed in the eastern tropical Pacific.

27. SCOMBERESOCIDAE
(27 occurrences, 153 specimens)

Two species of Scomberescocidae were taken on ETP II—*Scomberesox saurus* L. (18 occurrences, 52 specimens) and *Cololabis adocetus* Böhlke (9 occurrences, 101 specimens). The

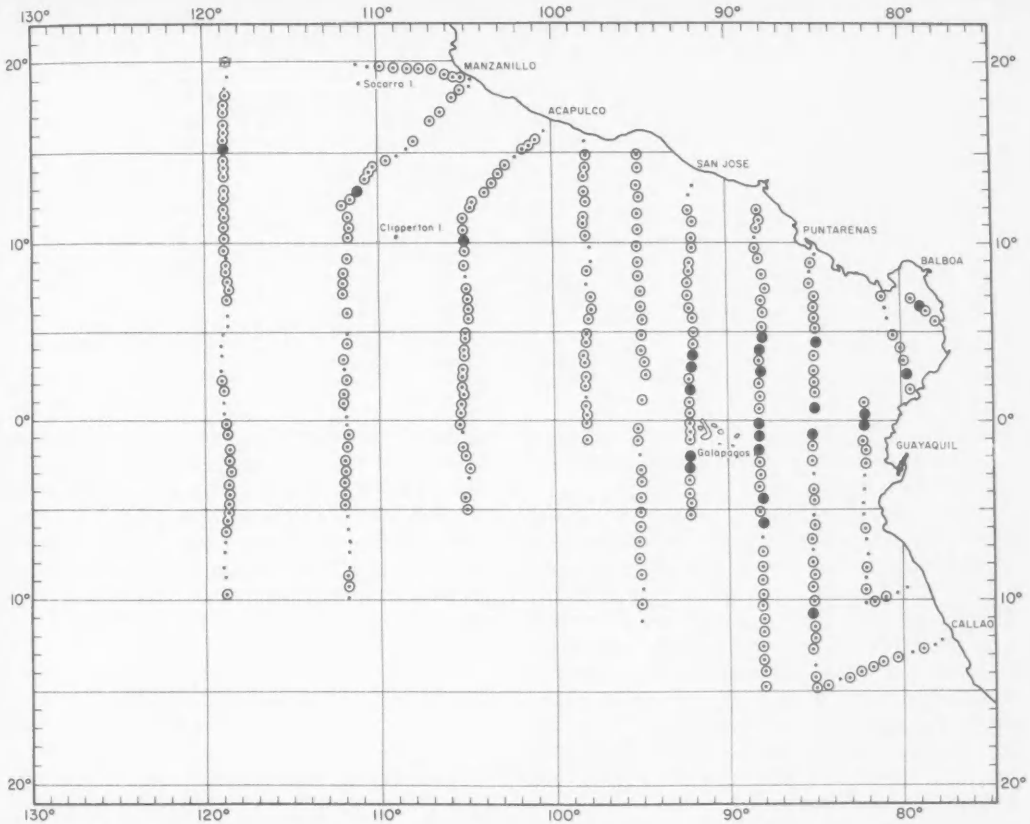

FIGURE 16.—Distribution of larvae of the beryciform family Melamphaidae on ETP II. Collections of 1-10 larvae are shown as open circles with dot, collections of 11 or more larvae as large solid circles; negative hauls are shown as small solid circles.

word "specimen" is used intentionally because some juveniles as well as larvae are included in the above counts. A number of the specimens were x-rayed in order to obtain vertebral counts to verify identification. All occurrences of the small tropical saury, *Cololabis adocetus*, were along long 95°W at nine contiguous stations (Figure 14); surface temperatures ranged between 19.5° and 21.5°C at these stations. *Scomberesox* larvae occurred in a broad coastal belt, shoreward of *C. adocetus*, extending from near the equator to the southernmost line occupied on ETP II (Figure 14); surface temperatures ranged between 15.8° and 19.5°C at these stations. Actually *Scomberesox* eggs and larvae were commonly taken in the pattern occupied by *Yelcho* off Chile as part of ETP II—MARCHILE VI. Collections obtained from surface tows as well as from oblique net hauls were available from MARCHILE VI. Five short lines of stations normal to the trend of the Chilean coastline were occupied on MARCHILE VI, between lat 18°30′ and 33°S. *Scomberesox* eggs and larvae were sampled best in surface hauls. *Scomberesox* eggs were taken in 17 of 20 surface hauls and *Scomberesox* larvae in 10 surface

TABLE 21.—Measurements of eggs of *Scomberesox saurus* collected on EASTROPAC II, including collections made off Chile by *Yelcho* (MARCHILE VI).

Collection	Type of haul	Locality of collection		Number eggs measured	Range in egg diameter (mm)	Average diameter (mm)	Surface water temperature (°C)
		Lat S	Long W				
MAR. 5.4	Surface	33°05.3′	73°20.5′	25	2.41-2.67	2.52	12.50
MAR. 4.4	Oblique	28°30.6′	72°43.2′	23	2.39-2.65	2.52	12.09
ETP 47.177	Oblique	06°35.0′	85°08.5′	31	2.31-2.60	2.44	18.14
MAR. 4.1	Surface	28°30.2′	71°40.1′	30	2.26-2.62	2.43	11.93
MAR. 3.2	Surface	23°42.5′	71°35.0′	25	2.24-2.45	2.36	14.39
ETP 47.145	Oblique	14°17.8′	83°03.7′	14	2.26-2.43	2.35	18.28
MAR. 1.8	Surface	18°27.6′	73°06.1′	25	2.24-2.51	2.34	15.81 (10 m)
ETP 47.134	Oblique	12°56.5′	79°27.8′	16	2.21-2.48	2.34	16.62
ETP 47.103	Oblique	10°09.0′	82°08.5′	25	2.26-2.45	2.34	18.32
ETP 47.107	Oblique	09°50.0′	80°53.0′	16	2.26-2.46	2.34	17.74
MAR. 2.1	Surface	20°09.0′	70°31.8′	25	2.15-2.45	2.33	15.77 (10 m)
MAR. 1.4	Surface	18°32.0′	71°42.0′	25	2.17-2.45	2.32	15.92 (10 m)
MAR. 2.4	Surface	20°10.8′	71°33.2′	25	2.19-2.45	2.32	15.74 (10 m)

hauls on MARCHILE VI. Hence young of *Scomberesox* have a north-south extent off South America of at least 1,860 miles.

Scomberesox eggs are approximately round and occur singly—lacking the attachment filaments characteristic of most eggs of fishes in the suborder Exocoetoidei (see in this regard Orton, 1964). The egg shell, however, is ornamented with minute closely spaced swellings. Eggs from 13 collections were measured (eggs measured in widest dimensions as they were not truly spherical); the data are summarized in Table 21. The range in egg size was from 2.15 to 2.67 mm; the range in egg diameter means for the 13 collections was from 2.32 to 2.52 mm. Eggs in the majority of collections (9 of 13) were quite similar in average diameters, ranging between 2.32 and 2.36 mm. Three of the four collections of eggs with larger average diameters were taken on the southernmost two lines of the *Yelcho* pattern. However, the collection of eggs made nearest to the equator (lat 6°35′) also was in this group of larger eggs.

30. APOGONIDAE

(66 occurrences, 283 larvae)

This family contains both oceanic and coastal species. Larvae of coastal apogonids were taken in four hauls off Central America and northern South America. The remainder of the larvae (62 occurrences, 278 larvae) were those of *Howella pammelas* (Heller and Snodgrass). Larvae of this species were most common to the north of the equator in a broad band extending offshore between 0° and lat 9°N. Only three occurrences were found to the north of this band and 11 to the south. This species was not limited in its distribution to particular water masses.

34. CARANGIDAE

(36 occurrences, 224 larvae)

Larvae of the pilotfish, *Naucrates ductor* (L.), with 18 occurrences, 27 larvae (Figure 17), was the most widely distributed carangid on ETP II. Over half of the carangid larvae were obtained at two coastal stations—45 larvae at 46.135 and 69 larvae at 47.527. As on ETP I, a number of kinds of carangid larvae were taken, including *Chloroscombrus orqueta* Jordan and Gilbert, *Selene brevoorti* (Gill), and *Caranx* spp.

37. CORYPHAENIDAE

(109 occurrences, 185 larvae)

Larvae of the dolphin, *Coryphaena* spp., were taken almost exclusively to the north of the equator (105 occurrences, 180 larvae) on ETP II; three of the four occurrences to the south of the equator were at stations immediately adjacent to the equator. *Coryphaena* larvae were

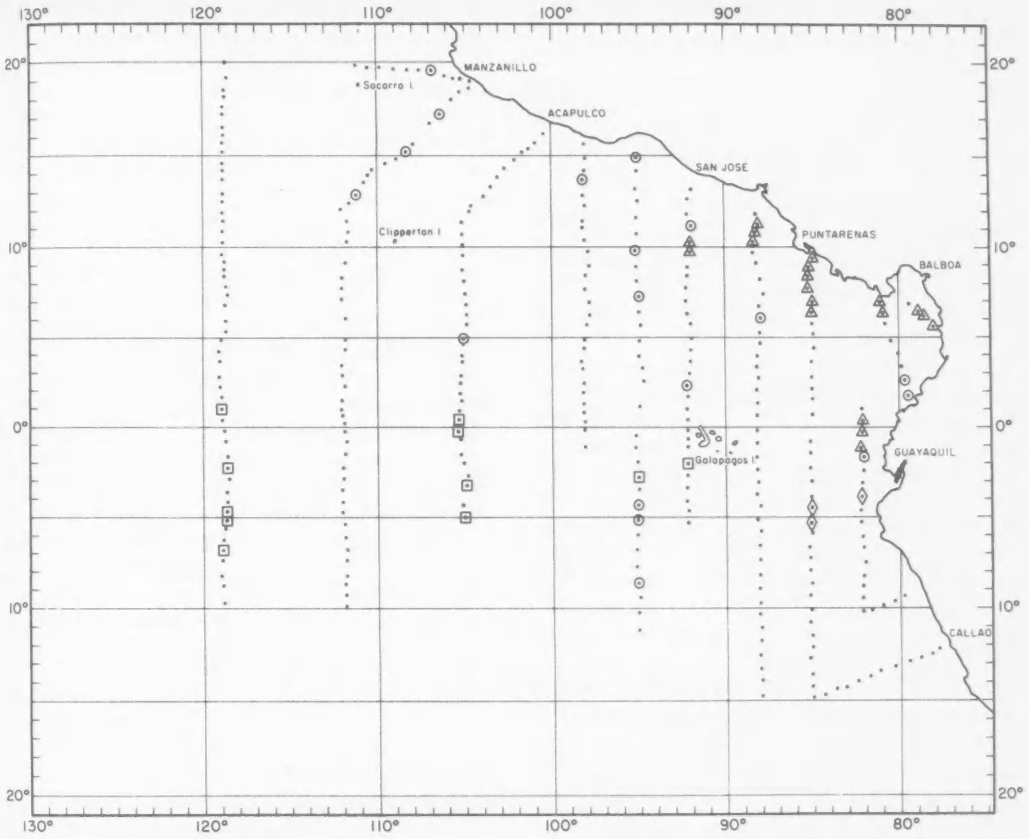

FIGURE 17.—Distribution of larvae of the carangid, *Naucrates ductor* (open circle with dot), of the tetragonurid, *Tetragonurus* spp. (open square with dot), and of the trichiurids, *Lepidopus* sp. (open diamond with dot) and *Trichiurus lepturus* (open triangle with dot); negative hauls are shown as small solid circles.

taken throughout the coverage on ETP I but at a lesser proportion of the stations; in equivalent coverage, 97 larvae were taken in 67 collections on ETP I. Dolphin larvae provide one of the more striking examples of a marked difference in the distributional pattern of larvae as between ETP I and ETP II.

Eggs and newly hatched larvae have been described for *Coryphaena hippurus* L. by Mito (1960). The eggs are 1.2 to 1.6 mm, with a single oil globule 0.3 to 0.4 mm. The larvae are heavily pigmented, even at hatching. We have not found distinguishing characters to separate the larvae of *C. hippurus* from those of *C. equiselis*, hence have labelled our material as *Coryphaena* spp. After the vertebral column is developed, definitive identification can be made: *C. hippurus* has 31 vertebrae, *C. equiselis* has 33 (Collette, Gibbs, and Clipper, 1969). Parin (1968) reports that *C. hippurus* reproduces only in the littoral zone and that *C. equiselis* is the offshore spawner. If this pattern of spawning holds for the eastern Pacific, then the majority of larvae taken on EASTROPAC cruises were those of *C. equiselis*. As noted for this family in the first EASTROPAC paper (ETP I, 38) the

majority of the specimens obtained were early stage larvae, hence spawned in the area of collection.

38. GEMPYLIDAE

(112 occurrences, 370 larvae)

Two kinds of gempylid larvae were widely distributed in the EASTROPAC area on ETP II: larvae of *Gempylus serpens* Cuvier and Valenciennes (71 occurrences, 152 larvae) and *Nealotus tripes* Johnson (66 occurrences, 218 larvae).

Larvae of both species had a higher frequency of occurrence and greater abundance on ETP II. Distribution within the EASTROPAC area also was different in the two multivessel surveys. The more widespread distributional pattern for *Gempylus serpens* was observed from the wider-ranging ETP I survey. Over a third of the occurrences of *Gempylus* larvae were in the portion of the ETP I pattern not replicated on ETP II (Ahlstrom, 1971, Figure 13). Larvae were taken throughout the ETP I pattern with as many records from south of the equator as to the north. In contrast, only three collections were made to the south of the equator on ETP II (Figure 4), but many more collections of *Gempylus* larvae were obtained to the north of the equator, particularly in the inner pattern occupied by *Rockaway*.

Changes in distribution of larvae of *Nealotus tripes* in the two surveys were not as marked as for *G. serpens*. On both surveys the majority of the occurrences of *Nealotus* larvae were in the inner half of the ETP pattern; heaviest concentration of larvae on ETP II was in an equatorial band between circa lat 5°N and 3°S. Fewer *Nealotus* larvae were taken in the inner pattern off Peru, between circa lat 3° and 15°S, as compared with ETP I (ETP I, Figure 7).

39. GOBIIDAE

(53 occurrences, 384 larvae)

Larvae of several families of shore or bottom fishes have a much more widespread oceanic distribution than would be anticipated from the distribution of adults. In the EASTROPAC area this applies particularly to larvae of Gobiidae, Scorpaenidae, Labridae, Bothidae, and Cynoglossidae. Based on pigmentation and meristics a minimum of eight kinds of goby larvae were taken.

42. NOMEIDAE

(229 occurrences, 1,460 larvae)
And other Stromateiodei (14 occurrences, 16 larvae)

Four families of stromateoid, fishes were taken on EASTROPAC cruises: Amarsipidae, Nomeidae, Stromateidae, and Tetragonuridae. Three of these families contain oceanic species that are widely distributed in offshore waters; only fishes of the family Stromateidae are confined to coastal waters. Important papers dealing with stromateoid fishes include Grey (1955), Haedrich (1967, 1969), Haedrich and Horn (1969),[2] and Horn (1970).

In the EASTROPAC area, only the nomeids were common, occurring in about two-thirds of the collections made on ETP II. Larvae were obtained of two genera, *Cubiceps* and *Psenes;* larvae of the former were the more abundant, larvae of the latter were more diversified as to species represented.

Larvae of a species in the family Stromateidae, *Peprilus medius* (Peters), were taken at a single station on ETP II, 46.135 (2 larvae), but a larger collection was obtained at *Oceanographer* Station OP 168 (16 larvae).

Larvae of Tetragonuridae (11 occurrences, 12 larvae) occurred in an equatorial band between lat 2°N and 7°S, seaward of the Galapagos Islands (Figure 17). As noted in the first EASTROPAC report, larvae of two species were taken: *T. cuvieri* Risso and *T. atlanticus* Lowe.

Two specimens of *Amarsipus carlsbergi,* described by Haedrich (1969) as a monotypic representative of a new family Amarsipidae, were

[2] Haedrich, R. L., and M. H. Horn. 1969. A key to the stromateoid fishes. Woods Hole Oceanogr. Inst. Ref. #69-70, 46 p. (Unpublished manuscr.)

obtained on ETP II, and five specimens previously had been taken on ETP I. These had been identified as *Centrolophus*-like with the notation that they probably represented an undescribed form. Identification of the material as *Amarsipus carlsbergi* was made by Dr. Michael H. Horn. Since little is known about this species in the eastern Pacific, I am listing all catch localities.

ETP II = Station 45.346 at lat 14°38.2′N, long 109°37.1′W, Sept. 8, 1967, 1 specimen, 26.2 mm; Station 47.272 at lat 11°20.8′N, long 88°00.5′W, Aug. 31, 1967, 1 specimen, 15.0 mm.

ETP I = Station 11.066 at lat 06°49.8′N, long 118°55.5′W, Feb. 3, 1967, 1 specimen, 10.3 mm; Station 11.114 at lat 02°37.8′S, long 119°02.3′W, Feb. 7, 1967, 1 specimen, 30.0 mm; Station 11.306 at lat 12°03.5′N, long 126°00′W, Feb. 27, 1967, 1 specimen, 16.0 mm; Station 12.059 at lat 09°31.5′N, long 105°02.0′W, Feb. 22, 1967, 1 specimen, 7.2 mm; Station 12.246 at lat 06°12.0′N, long 112°00.5′W, Mar. 16, 1967, 1 specimen, 7.3 mm.

43. OPHIDIIDAE

(38 occurrences, 81 larvae)

A number of kinds of larvae of this complex family were taken on ETP II, mostly in a coastal band between Acapulco, Mexico, and central Peru, but six occurrences were in a loose cluster about the Galapagos Islands. Only one kind has been identified to genus as yet; this is a form with conspicuously large pectorals (11 occurrences, 15 larvae) whose larvae were clustered in the Gulf of Panama or immediately seaward. Dr. Daniel Cohen of the National Marine Fisheries Service has identified larger specimens (small juveniles) as *Brotula* sp. A characteristic of this genus observed on several specimens was the presence of two ural centra in the "urostyle." Garman (1899) described 22 species of ophidiid-brotulids from the eastern tropical Pacific, few of which have been retaken subsequently. However, the variety of kinds of ophidiid larvae in our material attests to a speciose fauna.

47. SCOMBRIDAE

(55 occurrences, 248 larvae)

Scombrid larvae were markedly less abundant in ETP II as compared with similar coverage on ETP I (163 occurrences, 1,840 larvae).

The majority of scombrid larvae from ETP II were those of *Auxis* sp. (34 occurrences, 151 larvae) or were too small to identify with certainty (30 occurrences, 84 larvae). The remaining scombrid larvae included the wahoo, *Acanthocybium solanderi* (Cuvier) (2 occurrences, 3 larvae) from Stations 45.065 and 46.004; the mackerel, *Scomber japonicus* Hottuyn, (2 occurrences, 4 larvae) from near the Galapagos Islands; bigeye tuna, *Thunnus obesus* Lowe, (1 occurrence, 1 larva); skipjack, *Katsuwonus pelamis* (Linnaeus), (2 occurrences, 2 larvae); yellowfin tuna, *Thunnus albacares* (Bonnaterre), (2 occurrences, 2 larvae). Scombrid larvae were given to W. Klawe of the Inter-American Tropical Tuna Commission for identification.

52. TRICHIURIDAE

(49 occurrences, 186 larvae)

In the ETP I contribution, I pointed out the similarity in appearance of larvae of *Diplospinus multistriatus* Maul and those of *Gempylus serpens*, and the problems this raised about the distribution of genera between Gempylidae and Trichiuridae and perhaps about the need for two families. Treating larvae of the two families separately in this paper was done only for convenience. The problems raised in the first ETP contribution still need to be solved.

Three kinds of trichiurid larvae were obtained on ETP II: larvae of *D. multistriatus* Maul, *Trichiurus lepturus* (L.), and *Lepidopus* sp.

The distribution of larvae of *D. multistriatus* (25 occurrences, 69 larvae) was strikingly similar on the two multivessel cruises (Figure 4 and Ahlstrom, 1971, Figure 14). On ETP II, all but two occurrences were in a compact group at the southern inner half of the ETP pattern between circa lat 8° and 15°S and offshore to long 95°W. Most ETP I collections of larvae of this species were obtained from this same

general area. The remaining two occurrences on ETP II were obtained at the northern, outer end of the pattern, again similar to the distribution of *Diplospinus* larvae on ETP I. On ETP II, there were no occurrences of *Diplospinus* larvae between these two widely separated groups; on ETP I two specimens were taken at intermediate localities. Larvae of this species have been obtained in a number of collections made in the North Pacific central water mass, with best distributional information from the NORPAC Expedition of August 1955. It is not taken in California Current waters, hence the distribution in the Humboldt Current waters off Peru does not have a mirror-image replication in the California Current, as has been found for a number of species.

Larvae of *Trichiurus lepturus* (20 occurrences, 106 larvae) were taken in a coastal band on ETP II (Figure 17). Eggs of this species are readily identified and occurred in many of the hauls containing *Trichiurus* larvae and in some additional hauls. Interestingly enough, larvae of this species were not obtained in ETP I collections, hence this is another exception to the general pattern of year-long reproduction by tropical pelagic fishes. Unlike larvae of *Gempylus* or *Nealotus*, which were widely distributed in the EASTROPAC area, larvae of this species appear to have a restricted, coastal distribution.

Larvae of *Lepidopus* sp. (3 occurrences, 9 larvae) were taken in contiguous stations at about lat 5°S off Peru (Figure 17). Larvae of *Lepidopus* were taken in more hauls on ETP I (7 occurrences, 25 larvae, Ahlstrom, 1971, Figure 14), all located between the equator and lat 5°N and offshore to long 92°W.

This change in area of spawning of *Lepidopus* from north of the equator on ETP I to the south of the equator on ETP II may not be significant, because of the paucity of positive hauls. If real, one can only surmise as to whether the two populations were discrete, with separate spawning seasons on the two sides of the equator.

53. BOTHIDAE

(70 occurrences, 690 larvae)

Bothid larvae occurred in more hauls than on ETP I (70 versus 56 occurrences) and in larger numbers (690 versus 199 larvae). The species composition, however, was similar (Table 22). A short section will be devoted to each of the forms listed in this table.

Bothus leopardinus (Günther)

(27 occurrences, 97 larvae)

Only larvae of *B. leopardinus* have been ob-

TABLE 22.—Frequency of occurrence and relative abundance of larvae of flatfishes, Pleuronectiformes, on the second multivessel EASTROPAC survey, summarized by vessel pattern.

Flatfish larvae	*Washington* 45.000 series		*Undaunted* 46.000 series		*Rockaway* 47.000 series		Total EASTROPAC II	
	No. positive hauls	No. larvae	No. positive hauls	No. larvae	No. positive hauls	No. larvae	No. positive hauls	No. larvae
BOTHIDAE								
Bothus leopardinus	2	2	15	45	10	50	27	97
Citharichthys-Etropus	1	1	5	35	11	34	17	70
Cyclopsetta sp.	0	0	4	26	9	12	13	38
Engyophrys sancti-laurentii	0	0	0	0	3	3	3	3
Monolene sp.	0	0	0	0	1	1	1	1
Syacium ovale	6	15	17	201	32	264	55	480
Other Bothidae	1	1	0	0	0	0	1	1
Total Bothidae	7	19	28	307	35	364	70	690
CYNOGLOSSIDAE								
Symphurus spp.	2	5	16	109	38	248	56	362
Total Pleuronectiformes	7	24	30	416	46	612	83	1,052

tained in EASTROPAC collections. Although *B. mancus* (Broussonet) has been recorded from Clarion Island, off the west coast of Mexico (Norman, 1934), larvae of this species have not been obtained. Larval material of *B. mancus* has been examined from the vicinity of the Hawaiian Islands, and it differs from *B. leopardinus* in developing pigment on late stage larvae.

Larvae of *B. leopardinus* were distributed in a broad coastal band between Manzanillo, Mexico, and lat 4°N (Figure 8). This distribution is more restricted than that found on ETP I (Ahlstrom, 1971, Fig. 10). On ETP I, there were nine occurrences between lat 5°N and 6°S, as compared with a single occurrence on ETP II.

Citharichthys-Etropus
(17 occurrences, 70 larvae)

Although labeled *Citharichthys-Etropus* as for ETP I, the larvae taken on ETP II probably represent two species of *Citharichthys*, one with three elongated dorsal rays, the other with two elongated rays. Larvae of the latter were taken below the equator, either off Ecuador or near the Galapagos Islands (9 occurrences, 48 larvae). The form with three elongated dorsal rays was distributed in a coastal band between Manzanillo, Mexico, and Ecuador (8 occurrences, 22 larvae).

Cyclopsetta sp.
(13 occurrences, 38 larvae)

Larvae of *Cyclopsetta* sp. occurred in a broad coastal band between lat 15°N and circa lat 5°S. The larvae have been identified tentatively as *C. querna* (Jordan and Bollman). A developmental series was recently described by Gutherz (1970) for an Atlantic species of this genus, *C. fimbriata* (Goode and Bean). The Pacific and Atlantic species are similar in having opercular spination, a pair of sphenotic spines on the head, and nine or so elongated dorsal rays. They differ in several interesting respects. *C. fimbriata* transforms at a much smaller size, 14.0 mm, whereas the Pacific species can attain a length of at least 32 mm before transformation. The opercular spination is more strikingly developed on the Pacific form, and the pelvic fins become markedly more elongate, extending almost to the base of the caudal fin, whereas the fins attain only about 40% of this length proportionately in *C. fimbriata*.

Engyophrys sancti-laurentii (Jordan and Bollman)
(3 occurrences, 3 larvae)

Only three larvae of this species were obtained on ETP II, two from the vicinity of the Gulf of Panama and one from near Puntarenas, Costa Rica.

Monolene sp.
(1 occurrence, 1 larva)

A 16-mm specimen was obtained at Station 47.520. Larvae of *Monolene* develop a single, prominent elongated dorsal ray (2nd fin ray)—this ray was 6 mm long. Its meristics—D.82, A.63, Vert. 39—would fit *Monolene asaedai* Clark (Perkins, 1963) and possibly *M. dubiosa* Garman. The other two eastern Pacific species, *M. maculipinna* Garman and *M. danae Bruun*, have higher fin ray counts. Morrow (1957b) reported taking a 65-mm larva of *M. maculipinna* off Peru in a pelagic trawl fishing to 152-fm depth over rather deep water (1,300 fm). Morrow's specimen had the following meristics: D.98, A.79, Vert. 43. *Monolene danae* Bruun (1937) was described from a juvenile taken in a pelagic trawl off Panama by the *Dana* in 1922.

Syacium ovale (Günther)
(55 occurrences, 480 larvae)

Although larvae of *S. ovale* were the most common bothid flatfish collected on both ETP I and ETP II, it was decidedly more abundant in ETP II as compared with ETP I (24 occurrences, 84 larvae). Larvae of *Syacium* occurred in a broad coastal band between Manzanillo, Mexico, and Ecuador (Figure 3); only three collections were obtained to the south of the

TABLE 23.—Familial composition of Lophiiform larvae taken on the second multivessel EASTROPAC survey, summarized by vessel pattern.

Family	*Washington* 45.000 series		*Undaunted* 46.000 series		*Rockaway* 47.000 series		Total EASTROPAC II	
	No. positive hauls	No. larvae	No. positive hauls	No. larvae	No. positive hauls	No. larvae	No. positive hauls	No. larvae
Caulophrynidae	0	0	2	2	0	0	2	2
Centrophrynidae	1	1	0	0	0	0	1	1
Ceratiidae	0	0	2	3	3	5	5	8
Gigantactinidae	8	9	5	5	5	13	18	27
Himantolophidae	4	5	1	1	3	3	8	9
Linophrynidae	2	2	0	0	19	32	21	34
Melanocetidae	3	3	13	18	17	23	33	44
Oneirodidae	11	11	13	18	23	53	47	82
Unidentified ceratioids	9	11	7	7	10	16	26	34
Antennariidae	0	0	1	1	0	0	1	1
Lophiidae	0	0	1	1	0	0	1	1
Total Lophiiform	25	42	33	56	56	145	114	243

equator. Most larvae of *Syacium* were under 5 mm in standard length, and few were as large as 9 mm. At the latter size, the adult complement of fin rays were present in all fins except the pectoral, and the vertebral column was completely ossified. The vertebral count in specimens examined was 10 + 25.

54. CYNOGLOSSIDAE

(56 occurrences, 362 larvae)

Larvae of *Symphurus* spp. were taken in a broad coastal band between Manzanillo, Mexico, and northern Peru. *Symphurus* larvae were taken in slightly less hauls than on ETP I (56 versus 63 occurrences), but in slightly larger numbers (362 versus 304 larvae). Two kinds of *Symphurus* larvae were widely distributed, and three or four additional kinds occurred sparingly. Of the two common forms, one developed two elongated dorsal rays and the other six elongated dorsal rays.

56. LOPHIIFORMES

(114 occurrences, 243 larvae)

Lophiiform larvae were accumulated during the identification and enumeration of ETP II larvae, and then studied as a unit. Ten families were represented (Table 23). All but two of the specimens belonged to the subfamily Ceratioidei, a group of fishes whose ontogeny and taxonomy were dealt with in the impressive contribution of Bertelsen (1951). Ceratioid fishes have the most striking sexual dimorphism found in fishes. The males are parasitic in some ceratioids, free-living in others, but always quite small. Bertelsen showed that sex can be determined in the late larval stage; a papilliform illicium develops on the head of the female, but not on the male. A major achievement of Bertelsen was defining the distinguishing characteristics of larvae of all 10 ceratioid families. His work makes it possible to identify larger ceratioid larvae to the family level with assurance; however, small ceratioid larvae are much more difficult to identify because they have few distinguishing characters. Although Bertelsen worked out life history series to the generic or species level within all ceratioid families, ontogeny of the less common genera and species still remains unknown.

The ceratioids are a particularly difficult group in which to work out new developmental series. These cannot be based on larvae alone but must include transforming and adolescent specimens, preferably of both sexes, as well as adults. The EASTROPAC material, almost exclusively larvae, is inadequate for this purpose. Distributions of larvae are shown for five ceratioid families (Figure 18), as noted in the discussion of families. Most kinds of ceratioid larvae are quite rotund, hence aptly described as butterballs.

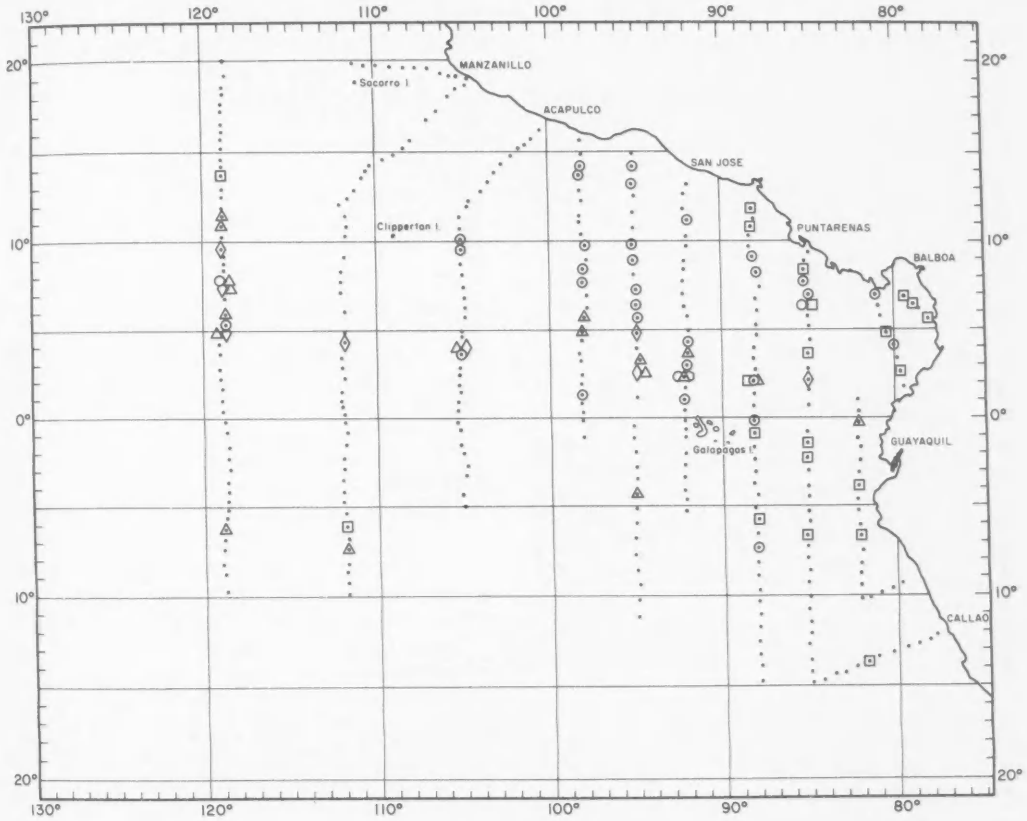

FIGURE 18.—Distribution of larvae of the lophiiform families Caulophrynidae (*Caulophryne jordani*) (open hexagon with dot), Gigantactinidae (*Gigantactis* sp.) (open triangle with dot), Himantolophidae (*Himantolophus* sp.) (open diamond with dot), Linophrynidae (2 or more genera represented) (open square with dot), and Melanocetidae (*Melanocetus* spp.) (open circle with dot); negative hauls are shown as small solid circles.

Caulophrynidae
(2 occurrences, 2 larvae)

Bertelsen referred all material of Caulophrynidae to a single species, *Caulophryne jordani* Goode and Bean. This is the only ceratioid fish known to develop pelvic fins. The two occurrences (Figure 18) were north of the equator in the pattern occupied by the middle vessel.

Centrophrynidae
(1 occurrence, 1 larva)

A single specimen was obtained of *Centrophyrne spinulosa* Regan and Trewavas in the offshore pattern (Station 45.325). Larvae of this species develop a digitiform barbel on the throat, a character unique to the species.

Ceratiidae
(5 occurrences, 8 larvae)

Larvae were obtained of two species of Ceratiidae, *Cryptopsaras couesi* Gill and *Ceratias holboelli* Kroyer. Bertelsen had previously recorded larvae of *C. couesi* from the eastern tropical Pacific, but not of *C. holboelli*. Ceratiid larvae are peculiarly "humpbacked," and the larger larvae of females develop "caruncles" on their backs. The caudal ray count in ceratioid fishes is constant at nine, except for two species that develop only eight caudal rays—*C. couesi* is one of these.

Gigantactinidae
(18 occurrences, 27 larvae)

Larvae of *Gigantactis* sp. were taken in a triangular-shaped wedge, broadest offshore (Figure 18). Even small larvae of this family can be identified with certainty, because of the large size of the pectoral fins.

Himantolophidae
(8 occurrences, 9 larvae)

Larvae of Himantolophidae were taken to the north of the equator, between lat 2° and 10°N in all vessel patterns (Figure 18). Larvae are similar to Bertelsen's series for *Himantolophus groenlandicus* Reinhardt, and he recorded specimens from Panama. Two additional species of *Himantolophus* have been described from Panama or vicinity: *H. azuerlucens* Beebe and Crane and *H. rostratus* Regan. I have recorded the EASTROPAC larvae simply as *Himantolophus* sp.

Linophrynidae
(21 occurrences, 34 larvae)

Several kinds of linophrynid larvae were taken, of which three were common—larvae of *Borophryne apogon* Regan, of the *Linophryne macrorhinus* group, and of the type designated by Bertelsen as "*Hyaloceratis*." All but two occurrences of linophrynid larvae were in the inner pattern shoreward of the Galapagos Islands (Figure 18). Most linophrynid larvae are more elongate than other ceratioid larvae and also have the lowest D and A counts, usually D3 and A3.

Melanocetidae
(33 occurrences, 44 larvae)

At least two kinds of *Melanocetus* larvae were obtained on ETP II, with most specimens referable to *M. polyactis* Regan and the remainder to *M. johnsoni* Günther. Most records of *Melanocetus* were from the northeast quadrant of the EASTROPAC pattern (Figure 18).

Oneirodidae
(47 occurrences, 82 larvae)

At least one-third of the ceratioid larvae taken on ETP II were referable to the family Oneirodidae. Bertelsen (1951) recorded seven kinds of oneirodid larvae belonging to six genera from collections made off Panama. All but one of these were taken in ETP II, together with a new record for the eastern Pacific. Oneirodid larvae sampled on ETP II included *Chaenophryne draco*-group, *Chaenophryne longiceps*-group, *Dolopichthys* sp., *Micropolichthys microlophus* (Regan), *Oneirodes eschrichti*-group, *Oneirodes melanocauda* Bertelsen, and *Pentherichthys* sp. Bertelsen could identify some oneirodid larvae only to species groups, including the three listed above. Bertelsen included 24 nominal species in the *Oneirodes eschrichti*-group, most of which were possibly synonyms.

Perhaps the most interesting record of an oneirodid larva from ETP II was of *Oneirodes melanocauda* from Station 47.008, off Panama. A male, 9.5 mm TL (6.5 mm SL), agreed in all essential characters with Bertelsen's description. This is one of the more heavily pigmented ceratioid larvae. The fin counts were D6, A4, P19, C9. Bertelsen based his description of *O. melanocauda* on four specimens, 8 to 21 mm TL, the

largest a metamorphosing female. These were obtained in the South China Sea, Indian Ocean, and Caribbean Sea. The EASTROPAC record is the first from the Pacific.

The caudal fin is usually unpigmented in ceratioid larvae, but caudal pigment is developed on several kinds of oneirodid larvae. Larvae of *O. melanocauda* have stippled pigment near the outer margin of the caudal rays. Larvae of *Penthrichthys* sp. have pigment sprinkled over much of the caudal fin rays. A third kind of oneirodid larva with streaks of caudal pigment between the rays was taken at Station 47.250 (ontogenetic series yet to be worked out).

The larvae of *Pentherichthys* from the eastern Pacific are probably referable to *P. atratus* (Regan and Trewavas). Collections were made at six stations in the inner pattern between lat 2° and 8°N. The 10 specimens ranged in total length from 3.2 to 7.0 mm. Bertelsen remarked on the paucity of small specimens of *Pentherichthys* in the *Dana* material; only 2 of 19 specimens were under 7.5 mm in total length.

Antennariidae
(1 occurrence, 1 larva)

The specimen, taken at an inshore Station, 46.132, on the middle pattern, was 7.5 mm SL and had fin counts of D-II + I-13, A7, P10, V5, C9. These counts could apply equally to species in the genera *Histrio* or *Antennarius*.

Lophiidae
(1 occurrence, 1 larva)

A specimen of a lophiid larvae was obtained in the middle pattern at Station 46.145. This specimen, 15.5 mm SL (25.0 mm TL), had the following counts: D-II + I + III — 8, A6, P16/17, V6, C8. This specimen is referable to the genus *Lophiomus*. Garman described two species of *Lophiomus* from the eastern Pacific with identical counts to the above. Norman in his unpublished synopsis considered the genus monotypic with Garman's species as junior synonyms of *L. setigerus* Vahl. The third dorsal spine is rather widely separated from an anterior group of two spines and a posterior group of three. The last ray in both the dorsal and anal fins was bifurcate to the base, differing in this respect from the last ray in ceratioid fishes, which is single. The larvae had two spines above the eye on either side of the head, differing in this character from the published larval series for *Lophius piscatorius* and *L. americanus* (Tåning, 1923); the pectoral fins were considerably smaller and compact.

57. OTHER IDENTIFIED
(23 occurrences, 51 larvae)

Two of the families, Amarsipidae and Stromateidae, have been discussed in the section dealing with Nomeidae and other Stromateiodei (No. 42). Other families included under "other identified" include Eutaeniophoridae (2 occurrences, 2 larvae), Gadidae (7 occurrences, 10 larvae), Callionymidae (2 occurrences, 2 larvae), Fistulariidae (1 occurrence, 1 larva), Gerridae-*Eucinostomus* sp. (4 occurrences, 15 larvae), Microdesmidae (4 occurrences, 6 larvae), Pomadasyidae-*Anisotremus* sp. (2 occurrences, 7 larvae), and Tetradontidae (1 occurrence, 1 larva).

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APPENDIX TABLE 1.—Counts of fish larvae, tabulated by family, for all stations occupied on the second multivessel EASTROPAC survey (EASTROPAC II).

STATION NUMBER	Myctophidae	Gonostomatidae	Sternoptychidae	Chauliodontidae	Idiacanthidae	Other Stomiatoidei	Bathylagidae	Paralepididae	Scopelarchidae	Melamphaidae	Bregmacerotidae	Exocoetidae	Trachypteridae	Apogonidae	Bramidae	Chiasmodontidae	Coryphaenidae	Nomeidae	Scombridae	Other identified larvae	Unidentified larvae	Disintegrated larvae	Total fish larvae
45.016	12	14	.	.	.	2	.	2	2	2	.	.	.	.	.	.	.	.	.	.	2	1	37
45.018	35	86	2	.	2	1	.	3	2	.	.	.	.	.	.	2	1	.	.	2	.	.	136
45.020	14	5	3	.	1	1	.	.	.	.	4	.	.	.	.	.	.	1	.	1	.	1	31
45.021	13	17	2	.	1	6	.	3	.	1	4	.	.	.	.	3	1	.	.	2	.	1	54
45.023	61	106	.	.	.	3	.	2	.	2	8	.	.	.	.	1	2	1	.	2	1	.	189
45.024	86	96	1	.	1	3	.	3	.	2	2	.	.	.	.	.	1	1	.	3	.	5	204
45.026	40	30	.	.	9	.	4	4	.	10	3	.	.	.	.	.	2	3	1	2	2	2	112
45.028	24	22	.	.	2	5	9	4	3	1	3	.	.	.	.	.	.	8	.	1	1	1	84
45.030	34	60	.	.	8	.	.	2	1	2	.	.	.	.	.	.	.	9	.	2	.	3	121
45.032	158	111	.	.	14	1	7	3	1	12	5	.	.	.	.	2	2	17	.	10	.	10	353
45.034	146	37	.	.	8	2	1	1	4	2	9	.	.	.	.	1	.	1	.	1	2	9	224
45.035	40	29	.	.	7	.	2	.	3	4	4	1	.	.	.	.	.	9	.	3	4	1	107
45.037	41	25	1	.	18	4	10	1	.	2	11	.	.	.	.	1	.	2	.	1	4	3	124
45.039	77	82	.	.	7	3	1	4	12	4	11	.	.	.	.	2	.	2	.	5	5	1	216
45.041	29	49	.	.	2	4	8	1	4	4	9	.	.	.	.	.	.	1	.	.	10	1	122
45.043	17	16	.	.	2	.	5	3	1	5	4	.	.	.	.	1	.	6	.	3	3	1	67
45.044	50	41	1	.	3	.	4	4	5	2	4	.	.	.	.	.	.	4	.	1	3	5	127
45.046	43	57	23	.	43	.	2	1	6	6	8	.	.	.	1	5	2	5	.	2	.	1	205
45.048	25	21	12	.	9	.	2	1	1	6	1	2	.	.	1	1	1	3	.	2	.	4	92
45.050	19	3	6	.	1	.	1	2	.	2	.	.	.	.	.	.	.	1	.	2	2	1	40
45.051	87	15	14	.	.	.	4	1	.	.	1	.	.	.	.	.	1	.	.	2	.	.	125
45.053	75	19	31	.	.	.	.	2	.	3	11	.	.	2	1	.	.	.	.	4	.	3	151
45.054	44	3	16	1	.	.	1	.	.	4	24	.	.	1	.	.	.	.	.	1	1	1	97
45.056	22	6	20	.	.	.	.	1	.	2	23	.	1	.	.	.	2	1	.	5	.	7	90
45.058	146	18	13	.	2	1	1	6	.	2	11	.	1	11	1	.	.	.	.	8	2	5	228
45.060	82	4	2	.	5	8	1	3	2	5	29	.	.	13	1	.	.	1	.	3	2	7	168
45.063	29	46	2	.	2	14	1	3	.	.	9	.	.	10	2	2	2	.	.	6	1	9	138
45.065	116	374	9	.	6	26	.	25	.	.	1	.	.	29	1	2	3	5	3	11	.	23	634
45.067	185	584	37	9	2	48	3	56	.	.	.	.	1	12	3	.	1	5	1	31	3	11	992
45.071	42	40	7	.	.	3	.	5	.	.	2	.	.	11	1	.	1	3	.	5	.	1	121
45.073	65	68	14	.	.	2	2	5	.	.	1	.	.	22	.	.	.	3	.	4	1	16	203
45.078	71	107	10	.	.	.	1	6	2	.	3	.	.	3	1	.	.	4	.	2	.	2	212
45.083	37	26	13	.	.	1	.	5	.	1	.	.	.	11	.	.	2	4	.	1	.	4	105
45.086	65	77	2	1	.	2	3	9	.	5	3	.	.	1	.	.	.	2	.	.	.	21	191
45.090	47	67	3	1	.	3	8	5	.	.	.	.	.	1	.	1	.	2	.	8	.	12	156
45.094	150	107	12	.	.	3	6	27	.	.	1	.	.	2	.	2	1	2	.	.	.	33	346
45.098	43	16	3	.	.	.	2	8	.	1	.	.	.	1	.	.	1	.	.	.	.	10	85
45.102	136	82	12	.	.	5	1	24	.	7	.	.	.	2	.	1	.	1	.	1	.	16	288
45.106	265	21	21	.	.	2	5	4	1	5	.	1	.	.	.	1	.	2	.	1	3	22	354
45.110	545	32	188	.	.	5	12	5	1	4	.	.	.	.	.	7	.	5	.	4	.	9	817
45.114	40	20	51	.	.	.	2	2	.	1	.	.	.	.	.	.	.	5	.	.	1	16	138
45.117	92	49	86	.	.	.	1	4	.	2	.	.	.	.	.	.	.	6	.	2	1	20	263
45.121	55	98	209	.	.	.	4	3	.	2	.	.	.	1	.	.	.	.	.	2	.	25	399
45.125	41	325	39	.	.	.	.	1	.	1	.	.	.	.	1	.	.	6	.	2	.	.	416
45.127	21	39	31	.	.	.	.	.	.	6	.	.	.	7	2	.	.	.	.	3	3	10	122
45.129	22	3	24	.	.	.	.	.	.	4	.	.	.	3	.	.	.	.	.	.	1	6	63
45.131	73	337	23	.	.	.	.	.	.	2	.	.	.	2	1	.	.	2	.	3	4	25	472
45.133	323	33	23	.	9	4	.	5	5	.	7	.	.	.	.	.	.	.	1	3	.	3	416
45.135	165	17	19	.	2	.	.	2	1	.	3	2	.	.	.	.	.	.	1	1	4	10	227
45.137	11	.	12	1	.	.	.	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	27
45.139	24	2	3	1	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	3	36
45.146	106	87	49	8	.	.	.	11	10	1	.	.	.	.	.	.	.	.	.	2	20	44	338

APPENDIX TABLE 1.—Counts of fish larvae, tabulated by family, for all stations occupied on the second multivessel EASTROPAC survey (EASTROPAC II).—*Continued.*

STATION NUMBER	Myctophidae	Gonostomatidae	Sternoptychidae	Chauliodontidae	Idiacanthidae	Other Stomiatoidei	Bathylagidae	Paralepididae	Scopelarchidae	Melamphaidae	Bregmacerotidae	Exocoetidae	Trachypteridae	Apogonidae	Bramidae	Chiasmodontidae	Coryphaenidae	Nomeidae	Scombridae	Other identified larvae	Unidentified larvae	Disintegrated larvae	Total fish larvae
45.163	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	8
45.165	152	65	212	1	6	3	.	1	4	2	8	.	.	.	.	.	.	.	.	3	2	12	471
45.167	86	6	10	.	.	.	.	.	2	2	.	.	.	.	2	.	.	1	.	.	.	10	119
45.169	56	15	1	.	.	.	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.	8	82
45.171	26	1	12	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	9	50
45.173	10	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	13
45.175	62	27	29	.	.	.	.	1	.	.	.	.	.	1	1	.	.	1	.	2	.	3	127
45.177	70	140	46	.	.	.	.	5	.	.	.	.	.	.	1	.	.	7	.	3	.	1	281
45.179	59	33	8	.	.	.	.	1	1	1	.	.	.	.	.	.	.	1	.	.	.	9	113
45.183	26	14	70	.	.	.	4	4	.	2	.	.	.	.	.	.	.	.	.	1	.	2	123
45.187	255	14	87	.	.	.	16	3	.	2	.	.	.	.	.	.	.	.	.	3	.	2	382
45.191	144	15	80	.	.	.	5	17	.	5	.	.	.	.	.	1	.	.	.	1	.	4	272
45.194	49	4	40	.	.	.	3	11	.	1	.	.	.	.	.	.	.	1	.	.	.	4	113
45.198	251	21	31	.	.	3	7	22	.	1	.	.	.	.	.	1	.	.	.	2	.	11	350
45.202	53	19	5	.	.	1	2	9	.	1	.	.	.	.	.	.	.	.	.	2	.	.	92
45.206	22	3	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	30
45.283	102	13	7	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	2	.	3	129
45.287	25	82	1	.	.	.	2	3	.	.	.	.	.	.	.	.	.	.	.	.	1	.	114
45.289	157	125	1	.	.	.	2	16	.	1	.	.	.	.	.	1	.	.	.	1	.	2	306
45.293	157	58	13	.	2	4	4	11	1	2	2	.	1	2	1	1	.	.	.	2	2	2	265
45.297	231	107	14	.	1	15	7	17	2	6	11	.	.	19	.	.	1	.	.	.	1	8	440
45.301	24	26	13	.	.	4	8	5	.	.	3	.	1	2	.	1	1	1	.	4	.	.	93
45.305	119	1040	17	.	1	3	2	.	1	1	6	.	1	.	.	.	3	10	.	1	.	9	1217
45.309	44	150	22	1	1	8	.	4	1	1	2	.	.	3	.	.	3	2	.	2	.	7	251
45.313	49	35	5	.	1	4	2	6	.	.	2	.	.	4	.	.	1	.	.	1	.	9	119
45.316	41	34	8	1	.	3	1	2	.	1	4	.	.	.	1	.	.	.	.	1	.	2	99
45.319	32	46	17	.	.	2	.	3	.	3	4	.	.	1	.	.	.	.	.	2	.	1	111
45.321	45	13	20	.	.	.	2	.	.	7	4	.	.	.	.	.	.	.	.	1	1	1	94
45.323	51	4	1	.	.	3	1	2	.	7	1	.	.	.	.	1	.	.	.	1	1	1	74
45.325	1002	28	19	.	1	.	42	3	1	7	1	.	1	.	6	.	1	8	1	4	.	3	1128
45.329	69	4	11	.	8	.	3	1	.	3	.	1	.	.	1	.	1	4	.	1	.	3	110
45.331	235	5	11	.	1	1	13	.	.	6	3	.	.	.	1	.	.	10	.	1	2	1	290
45.333	108	28	10	.	.	2	5	1	.	4	3	1	.	.	.	.	1	25	.	13	.	.	201
45.335	65	32	2	.	14	5	8	3	3	1	1	.	.	.	.	.	1	9	.	8	1	2	155
45.337	49	12	6	.	21	12	1	3	1	12	6	.	.	.	.	2	2	14	.	1	.	16	158
45.339	26	8	.	.	15	4	2	.	.	7	8	1	.	.	.	3	1	5	.	9	2	9	100
45.341	47	70	.	.	7	1	3	4	4	3	2	.	.	.	.	.	1	1	.	1	.	.	144
45.343	17	32	.	.	8	1	2	2	.	2	2	3	.	.	.	.	1	4	.	2	.	1	77
45.344	21	37	.	.	6	2	1	3	1	3	3	1	1	.	.	.	1	11	.	4	.	4	99
45.346	19	19	.	.	2	1	.	4	.	3	2	.	.	.	.	.	1	4	.	2	.	1	58
45.348	30	120	.	.	3	.	.	4	4	.	.	.	.	.	.	.	.	2	.	3	.	.	166
45.350	70	297	.	.	1	2	.	1	.	.	.	.	.	.	.	.	.	6	.	1	.	5	383
45.352	29	66	.	.	.	.	3	2	.	1	1	1	.	.	.	.	.	3	.	.	.	10	116
45.356	69	153	.	.	5	.	11	6	1	1	.	3	.	.	.	.	2	19	9	1	2	.	282
45.358	98	107	.	.	1	.	1	.	.	4	2	4	1	.	.	.	1	6	5	2	3	7	242
45.360	18	37	.	.	.	1	7	2	.	1	.	.	.	.	.	.	.	9	5	4	3	4	91
45.362	36	31	.	.	.	.	6	8	.	4	2	.	.	.	.	.	1	8	6	17	8	1	128
45.365	99	55	.	.	.	.	1	1	.	.	27	.	.	.	.	.	.	.	4	103	15	6	311
45.367	23	10	.	.	1	1	7	1	.	.	3	.	.	.	.	.	.	.	.	19	.	73	138
45.369	101	106	.	.	.	2	3	10	1	2	25	.	.	.	.	.	1	7	12	61	11	15	357
45.371	120	239	.	.	1	2	13	4	3	10	13	.	1	.	.	.	.	7	6	10	6	11	446
45.373	117	149	.	.	1	.	14	1	.	2	.	2	.	.	.	.	.	13	9	10	3	.	321

APPENDIX TABLE 1.—Counts of fish larvae, tabulated by family, for all stations occupied on the second multivessel EASTROPAC survey (EASTROPAC II).—*Continued.*

STATION NUMBER	Myctophidae	Gonostomatidae	Sternoptychidae	Chauliodontidae	Idiacanthidae	Other Stomiatoidei	Bathylagidae	Paralepididae	Scopelarchidae	Melamphaidae	Bregmacerotidae	Exocoetidae	Trachypteridae	Apogonidae	Bramidae	Chiasmodontidae	Coryphaenidae	Nomeidae	Scombridae	Other identified larvae	Unidentified larvae	Disintegrated larvae	Total fish larvae
45.375	34	39	.	.	.	1	3	1	.	1	2	2	.	.	.	.	.	2	.	4	.	2	91
45.377	67	86	.	.	.	2	8	3	1	3	1	.	.	.	.	.	2	18	6	11	.	18	226
45.379	199	805	.	.	.	1	2	6	2	3	3	1	.	.	.	.	.	3	.	10	12	1	1048
45.381	98	248	.	.	1	.	4	3	.	2	3	.	.	.	.	.	.	2	.	3	2	5	371
45.383	40	20	.	.	.	.	4	.	.	4	.	.	.	.	.	.	.	.	.	2	5	3	78
45.385	19	60	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	83
45.387	26	429	.	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	461
CRUISE	46																						
46.002	14	19	.	.	.	.	2	1	.	.	.	2	.	.	.	.	1	14	.	2	2	1	58
46.004	103	122	.	.	11	3	4	18	2	5	3	.	.	.	.	.	7	21	2	3	2	3	309
46.006	30	19	.	.	5	1	1	2	.	1	5	.	1	.	.	1	.	9	.	1	4	1	81
46.007	10	28	.	.	1	.	.	2	.	4	1	.	.	.	.	.	.	14	.	1	.	6	67
46.009	17	23	.	.	2	.	1	2	.	.	1	.	.	1	.	.	2	8	.	2	.	3	62
46.011	60	72	.	.	4	2	1	5	3	5	1	1	.	.	.	1	3	16	.	2	1	.	177
46.013	89	51	.	.	2	5	.	2	5	1	2	.	.	.	.	.	1	7	.	1	.	.	166
46.015	18	17	.	.	2	.	1	11	.	4	7	.	.	.	.	.	1	8	.	1	.	.	70
46.017	25	4	.	.	11	.	5	.	1	1	9	.	.	.	.	.	2	1	.	2	1	.	62
46.019	285	148	.	.	17	2	1	2	9	1	9	.	1	1	.	.	2	.	.	3	.	.	481
46.020	160	80	.	.	16	2	10	3	4	2	2	1	.	.	.	.	2	1	1	.	1	.	285
46.022	38	14	11	.	4	.	1	2	1	8	1	2	.	.	1	1	1	8	3	1	1	2	100
46.024	64	27	2	.	3	1	5	1	3	2	2	1	.	.	2	.	.	7	1	2	2	.	125
46.026	206	140	2	.	2	.	5	6	4	11	3	1	.	1	.	4	.	13	3	.	2	.	403
46.028	412	157	10	.	9	2	12	6	1	10	4	.	.	.	1	.	3	15	2	2	1	8	655
46.030	85	7	12	.	3	2	8	.	.	2	2	.	.	.	.	.	1	2	.	.	.	7	131
46.032	9	.	8	.	.	.	1	.	.	.	.	.	.	.	.	1	.	1	.	1	.	.	21
46.034	152	40	17	1	.	3	5	3	1	1	9	.	.	.	1	1	1	1	.	7	2	3	248
46.036	436	127	28	.	2	1	7	8	1	4	4	1	.	1	.	1	3	.	1	3	.	6	634
46.038	20	7	10	.	.	.	3	1	1	2	.	1	.	.	.	.	.	1	.	.	.	3	49
46.040	25	20	8	.	.	1	.	4	.	1	.	.	.	1	2	.	.	.	1	3	.	4	69
46.042	62	133	5	.	1	.	4	.	.	2	1	2	.	1	.	.	.	.	1	1	1	4	218
46.044	89	96	21	.	.	1	1	1	.	5	1	1	.	1	.	.	.	1	.	1	2	11	232
46.046	78	57	22	.	.	2	1	2	3	3	.	.	.	2	1	.	.	.	1	8	.	11	191
46.048	63	54	24	.	1	.	10	3	.	5	4	1	.	4	1	.	1	.	.	3	3	4	181
46.050	250	184	18	.	.	1	12	24	1	7	11	.	.	11	1	1	.	4	.	3	4	15	547
46.052	319	217	23	.	3	.	7	18	1	3	4	.	.	11	1	.	1	2	.	13	3	5	631
46.054	211	181	22	.	.	3	20	23	1	6	9	.	.	.	.	2	.	.	.	2	3	14	497
46.055	100	73	10	.	1	1	5	18	4	4	4	.	.	3	3	4	.	3	.	.	.	16	249
46.057	751	649	3	.	.	2	10	70	2	3	.	.	.	2	.	3	.	3	.	6	2	.	1506
46.059	494	504	.	.	.	5	2	59	2	1	1	.	.	.	.	1	.	2	.	22	.	5	1098
46.061	148	98	5	1	.	1	3	23	.	1	.	.	.	.	.	.	.	.	.	14	.	72	366
46.063	48	19	8	3	.	.	2	10	.	.	.	.	.	.	.	.	.	1	.	.	5	20	116
46.065	404	97	14	.	.	5	4	50	.	2	.	.	.	.	.	6	.	.	.	2	.	8	592
46.067	269	121	20	.	.	2	5	18	.	1	.	.	.	.	.	.	.	.	.	2	3	20	461
46.069	116	55	23	.	.	.	22	53	.	4	.	.	.	.	.	.	.	.	.	5	33	20	331
46.071	72	27	34	.	.	.	14	22	.	.	.	.	.	.	.	.	.	.	.	4	3	16	192
46.075	35	21	32	.	.	.	5	17	.	4	.	.	.	.	.	.	.	.	.	.	.	6	120
46.077	36	19	12	.	.	1	1	3	.	1	.	.	1	1	.	1	.	.	.	3	.	.	79
46.079	408	30	14	.	.	22	23	31	.	2	.	.	.	.	.	.	.	1	.	4	.	1	536
46.082	61	46	13	.	.	5	17	15	.	2	.	.	.	.	.	.	.	1	.	8	.	8	176

APPENDIX TABLE 1.—Counts of fish larvae, tabulated by family, for all stations occupied on the second multivessel EASTROPAC survey (EASTROPAC II).—*Continued.*

STATION NUMBER	Myctophidae	Gonostomatidae	Sternoptychidae	Chauliodontidae	Idiacanthidae	Other Stomiatoidei	Bathylagidae	Paralepididae	Scopelarchidae	Melamphaidae	Bregmacerotidae	Exocoetidae	Trachypteridae	Apogonidae	Bramidae	Chiasmodontidae	Coryphaenidae	Nomeidae	Scombridae	Other identified larvae	Unidentified larvae	Disintegrated larvae	Total fish larvae
46.084	45	39	13	.	.	2	21	21	.	3	.	.	.	.	.	.	.	.	.	6	1	8	159
46.086	102	233	25	.	1	2	33	26	.	3	.	.	.	.	.	.	.	4	.	8	.	1	443
46.088	124	60	16	.	.	6	8	27	.	.	.	.	.	.	.	.	.	3	.	4	1	9	258
46.090	99	24	47	.	1	6	4	28	3	6	.	.	.	.	.	1	.	7	.	.	.	143	369
46.092	100	29	36	.	.	4	3	10	2	4	.	.	.	1	.	.	1	4	.	.	4	2	200
46.094	300	156	87	.	2	7	3	21	.	8	3	.	2	.	.	1	.	.	.	3	1	1	595
46.096	240	249	54	.	3	2	13	24	1	5	3	3	.	7	.	.	3	2	.	7	8	4	628
46.098	73	42	35	.	.	8	2	4	.	3	.	.	.	7	1	1	.	1	.	2	3	15	197
46.100	125	8	41	.	3	.	2	1	3	2	9	.	.	.	.	.	.	.	.	1	1	6	202
46.102	334	56	69	1	1	4	3	10	.	9	7	.	.	1	.	2	.	.	.	4	3	4	508
46.104	109	48	36	1	2	4	.	10	1	1	.	.	.	2	.	.	1	2	.	2	1	12	232
46.106	115	41	19	.	.	1	9	1	.	2	.	1	1	.	.	.	2	7	1	2	4	4	210
46.108	250	38	45	.	.	7	27	.	.	.	.	.	.	.	.	.	.	20	4	5	1	18	415
46.110	162	10	22	.	1	.	5	.	5	3	.	1	.	.	.	.	.	2	3	15	1	.	230
46.112	562	75	14	.	1	1	16	3	.	.	.	.	.	.	.	.	.	3	14	49	.	.	738
46.114	31	6	2	.	1	1	3	.	2	.	3	2	.	.	.	.	.	3	.	7	.	.	61
46.116	14	5	3	.	1	.	.	1	.	3	.	.	.	.	.	.	.	7	.	1	.	2	37
46.118	176	85	6	.	8	1	3	7	2	5	1	1	1	.	.	.	4	13	.	1	4	3	321
46.120	80	100	.	.	13	2	1	9	1	1	2	1	3	.	.	.	2	12	.	10	.	.	237
46.122	17	29	.	.	2	2	4	4	2	2	3	.	1	.	.	.	1	10	.	8	.	.	85
46.124	19	22	.	.	.	.	2	3	1	4	3	.	.	.	.	.	1	12	.	6	3	3	79
46.126	63	98	.	.	13	1	10	7	1	7	1	1	1	.	.	.	.	4	.	20	10	.	237
46.128	113	131	.	.	11	9	8	11	2	9	19	.	.	.	.	.	1	12	.	7	7	3	343
46.130	46	54	.	.	1	5	11	6	1	6	10	.	.	.	.	.	1	9	.	5	20	9	183
46.132	26	26	.	.	.	.	5	9	.	.	4	.	.	.	.	.	.	17	11	12	19	1	130
46.134	9	12	.	.	3	.	8	.	.	.	511	.	.	.	.	.	2	.	20	93	18	8	684
46.135	81	12	.	.	1	.	8	.	.	.	927	.	.	.	.	.	1	5	6	149	24	4	1218
46.137	201	28	1	.	1	1	24	.	.	7	9	.	.	.	.	.	.	4	.	278	.	7	561
46.139	175	52	1	.	1	.	11	1	1	6	1	.	.	.	.	.	.	15	3	15	.	1	283
46.141	438	20	4	1	1	2	18	1	1	4	.	4	1	.	2	.	1	6	.	8	3	3	518
46.143	113	15	30	.	1	.	10	.	1	2	1	.	.	.	1	.	.	7	1	3	2	5	201
46.145	282	119	24	.	3	2	38	3	.	2	.	.	1	.	.	.	2	4	2	4	2	1	489
46.147	484	41	49	.	2	1	41	1	3	4	.	.	.	.	.	.	.	5	1	4	.	8	642
46.149	1333	14	30	.	1	10	22	.	.	7	1	.	.	.	.	.	.	6	.	4	2	2	1432
46.151	1358	9	24	.	1	4	13	.	.	8	.	.	.	.	.	2	.	.	.	1	.	.	1420
46.153	2561	165	81	.	2	3	4	.	1	7	.	1	1	.	.	.	.	4	.	18	.	16	2864
46.155	973	140	67	.	4	9	6	1	.	8	1	.	.	.	2	1	2	3	3	11	.	3	1234
46.157	490	27	78	1	1	7	6	5	1	8	3	.	1	7	2	.	2	.	.	7	2	12	660
46.159	71	11	32	.	.	2	2	1	.	2	.	.	.	3	1	.	2	.	.	6	.	1	134
46.161	350	47	73	.	4	2	8	12	2	15	.	.	.	.	.	1	.	.	1	12	1	3	531
46.163	290	88	64	.	7	4	10	12	1	13	.	.	1	1	.	.	.	.	.	8	2	41	540
46.165	90	36	60	.	5	.	18	15	.	7	.	3	1	1	.	1	1	.	.	9	5	9	261
46.167	195	40	49	.	3	1	37	7	.	11	.	.	2	2	.	.	.	5	.	7	2	25	386
46.169	163	236	30	.	.	4	52	46	.	10	.	1	.	.	.	2	.	1	.	4	4	10	563
46.171	255	55	15	.	1	8	44	28	.	7	.	.	.	.	.	.	.	.	.	72	.	60	545
46.173	33	15	6	.	.	.	10	6	.	1	.	.	.	.	.	.	.	.	.	5	.	2	78
46.175	52	76	4	.	1	.	21	3	.	2	.	.	.	.	.	.	.	.	.	2	.	1	162
46.177	124	33	17	.	1	2	45	16	.	10	.	.	.	.	.	.	.	.	.	26	.	8	281
46.179	213	110	54	.	1	4	135	19	.	22	.	.	.	.	.	.	.	.	3	110	3	14	688
46.181	52	58	13	3	2	3	132	13	.	14	.	.	.	.	.	.	.	1	.	21	18	4	339
46.183	85	21	29	2	4	11	47	11	1	9	2	.	.	.	.	2	.	2	.	5	.	4	235
46.185	262	97	54	.	2	10	45	12	.	9	.	.	.	.	.	3	.	2	.	6	.	3	505

APPENDIX TABLE 1.—Counts of fish larvae, tabulated by family, for all stations occupied on the second multivessel EASTROPAC survey (EASTROPAC II).—*Continued.*

STATION NUMBER	Myctophidae	Gonostomatidae	Sternoptychidae	Chauliodontidae	Idiacanthidae	Other Stomiatoidei	Bathylagidae	Paralepididae	Scopelarchidae	Melamphaidae	Bregmacerotidae	Exocoetidae	Trachypteridae	Apogonidae	Bramidae	Chiasmodontidae	Coryphaenidae	Nomeidae	Scombridae	Other identified larvae	Unidentified larvae	Disintegrated larvae	Total fish larvae
46.187	516	42	23	.	1	1	17	7	2	2	.	.	.	.	1	.	.	2	.	6	3	6	629
46.189	236	5	19	1	.	1	8	.	1	4	.	.	.	.	.	.	.	.	.	1	1	1	278
CRUISE	47																						
47.001	97	63	6	.	.	.	4	2	.	2	15	.	.	.	1	.	1	1	.	42	.	.	234
47.005	287	206	21	.	3	.	6	6	1	8	22	.	.	1	.	.	1	2	.	81	6	17	668
47.008	257	49	5	.	9	2	7	2	3	13	4	.	.	.	.	.	.	.	.	70	1	7	429
47.011	161	26	4	.	2	1	3	1	1	5	21	.	.	.	.	.	.	2	.	32	2	2	263
47.019	370	234	2	.	.	.	5	8	.	3	.	.	.	2	1	.	.	.	.	145	63	10	843
47.022	169	29	26	.	1	5	3	.	.	.	.	.	.	.	.	.	.	3	.	17	2	10	265
47.025	83	58	5	.	3	1	4	3	.	.	4	1	.	.	.	.	.	1	.	10	1	2	176
47.028	264	118	40	.	16	.	14	15	2	9	5	.	.	.	.	.	1	1	.	52	15	10	562
47.032	208	141	72	.	4	2	15	10	2	8	5	.	1	.	1	.	1	7	.	22	2	8	509
47.034	139	36	8	.	3	1	7	27	.	3	5	.	.	.	1	.	.	2	.	45	7	18	302
47.035	223	73	23	.	16	2	20	43	.	11	7	1	.	.	.	.	.	4	.	29	1	10	463
47.040	205	85	29	.	5	2	8	24	.	4	34	.	.	.	.	.	1	3	.	127	18	22	567
47.049	64	109	20	.	1	8	26	50	.	6	.	2	.	.	.	.	1	11	.	12	2	35	347
47.053	265	102	9	.	2	8	27	27	.	12	.	.	1	.	.	.	.	17	.	82	7	21	580
47.057	300	116	5	.	.	13	50	29	.	11	.	1	.	.	1	.	2	33	.	114	6	50	731
47.061	79	20	9	1	.	4	11	17	.	7	22	.	.	.	.	3	.	12	.	33	4	9	231
47.065	99	93	7	.	.	11	30	5	.	4	8	54	.	.	.	.	.	8	.	22	5	19	365
47.069	140	51	64	.	.	8	143	10	.	5	.	.	.	1	1	3	.	1	.	38	6	9	480
47.070	90	18	13	.	.	11	188	8	.	.	.	.	.	.	.	1	.	5	.	34	2	.	370
47.074	138	14	19	.	1	9	301	5	.	.	.	.	.	.	.	.	.	2	.	65	11	23	587
47.078	11	5	5	.	.	.	64	2	.	.	.	.	.	.	.	.	.	.	.	9	.	6	102
47.082	119	6	13	.	.	.	80	7	.	.	.	.	.	.	.	.	.	.	.	29	1	2	257
47.086	248	11	59	.	.	.	530	.	3	2	.	.	.	.	.	.	.	.	.	127	2	20	1002
47.090	57	5	6	.	1	2	83	.	.	.	.	.	.	.	.	.	.	.	.	3	.	5	162
47.094	100	2	17	.	.	.	8	.	1	.	.	.	.	.	.	.	.	.	.	1	.	3	132
47.097	16	.	6	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	258	1	1	283
47.099	16	.	2	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	62	.	2	84
47.101	48	.	1	.	2	.	1	.	.	2	.	.	.	.	.	.	.	.	.	227	.	1	282
47.103	2	.	4	2	1	1	2	.	.	.	.	.	.	.	.	.	.	.	.	2	.	1	15
47.105	4	5	1	.	.	.	5	.	.	2	.	.	.	.	.	.	.	.	.	4	.	.	21
47.107	109	7	1	.	.	.	4	.	.	4	.	.	.	.	.	.	.	.	.	9	.	.	134
47.109	6	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	293	.	4	305
47.113	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	35	.	2	38
47.124	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	99	.	1	110
47.128	35	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	96	6	.	137
47.132	85	9	1	7	.	.	3	.	3	4	.	.	.	.	.	.	.	.	.	46	.	.	158
47.134	21	9	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	52
47.137	17	12	4	.	.	.	3	.	2	5	1	.	.	.	.	1	.	.	.	1	.	2	48
47.139	16	11	.	2	.	.	5	.	.	4	.	.	.	.	.	.	.	.	.	9	.	.	47
47.141	24	17	.	4	.	.	13	.	2	3	.	.	.	.	.	.	.	.	.	18	.	9	90
47.143	23	2	1	26	4	.	16	.	.	1	.	.	.	.	.	.	.	.	.	4	3	9	89
47.145	15	14	1	4	1	.	5	.	3	3	1	.	.	.	.	3	.	.	.	.	.	2	52
47.147	44	78	3	18	2	1	16	.	.	.	3	.	.	.	2	4	.	.	.	5	1	4	181
47.149	40	28	3	7	.	4	15	.	.	3	1	.	.	.	.	6	.	.	.	3	1	8	119
47.151	22	3	.	.	.	.	4	.	.	1	2	.	.	.	.	1	.	.	.	6	.	11	50
47.153	30	13	.	.	.	1	17	.	5	5	1	.	.	.	.	9	.	.	.	8	8	5	100

APPENDIX TABLE 1.—Counts of fish larvae, tabulated by family, for all stations occupied on the second multivessel EASTROPAC survey (EASTROPAC II).—*Continued.*

STATION NUMBER	Myctophidae	Gonostomatidae	Sternoptychidae	Chauliodontidae	Idiacanthidae	Other Stomiatoidei	Bathylagidae	Paralepididae	Scopelarchidae	Melamphaidae	Bregmacerotidae	Exocoetidae	Trachypteridae	Apogonidae	Bramidae	Chiasmodontidae	Coryphaenidae	Nomeidae	Scombridae	Other identified larvae	Unidentified larvae	Disintegrated larvae	Total fish larvae
47.155	.	3	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
47.157	109	77	8	16	3	.	27	.	1	2	1	.	.	.	.	11	.	.	.	8	3	8	274
47.159	17	11	.	7	.	.	14	.	1	5	.	1	.	.	.	.	.	.	.	1	1	4	62
47.162	11	5	.	.	.	.	6	.	.	3	.	.	.	.	.	.	.	1	.	2	.	1	29
47.164	25	37	.	1	.	.	10	.	.	12	.	.	.	.	.	.	.	2	.	2	.	5	94
47.166	28	21	4	.	.	.	1	.	1	3	.	.	3	.	.	1	.	2	.	.	.	.	64
47.168	6	1	1	.	.	.	3	.	1	3	.	.	.	.	1	3	.	1	.	1	3	3	27
47.171	66	39	15	.	.	3	9	.	.	4	.	.	.	.	.	.	.	8	.	.	1	4	149
47.173	251	166	31	.	.	8	17	.	6	3	.	.	.	.	.	.	.	23	.	2	.	11	518
47.175	327	95	4	2	.	4	16	.	1	.	.	.	.	.	.	.	.	5	.	15	1	.	470
47.177	119	100	10	.	.	69	157	4	1	1	.	.	.	.	.	.	.	19	.	12	.	40	532
47.179	228	14	1	.	2	11	189	.	3	2	.	.	.	.	.	1	.	3	.	3	.	42	499
47.181	150	32	7	1	.	12	59	.	1	.	.	.	.	.	.	.	.	.	.	11	.	3	276
47.185	350	31	45	1	3	12	140	23	4	5	.	.	.	.	.	2	.	1	.	27	.	14	658
47.189	28	5	8	.	.	8	97	3	1	4	.	.	.	.	.	.	.	.	.	5	.	26	185
47.193	2	2	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	8
47.197	97	9	13	.	2	23	123	4	.	5	.	.	.	.	.	1	.	2	.	17	2	8	306
47.201	392	152	24	.	1	12	140	20	.	10	.	.	.	.	.	9	.	2	.	8	.	54	824
47.205	109	48	27	.	.	23	152	20	.	17	1	1	.	.	1	2	.	4	.	8	3	125	541
47.213	769	440	43	.	14	3	58	26	.	25	.	2	2	.	.	.	.	43	.	43	5	40	1513
47.217	440	90	44	.	8	4	30	20	.	4	.	1	.	.	.	.	.	5	.	20	.	11	677
47.221	452	36	54	.	13	2	30	43	.	9	.	.	.	.	.	2	1	3	.	17	.	14	676
47.225	512	151	53	.	5	7	34	31	5	6	2	.	2	1	1	.	4	15	.	16	2	13	860
47.229	496	272	83	.	14	5	17	11	1	9	2	.	1	.	.	1	1	5	.	21	.	3	942
47.233	1441	249	95	2	42	6	14	31	5	18	2	1	1	.	2	1	3	3	1	16	5	37	1975
47.237	100	17	18	.	4	.	8	2	1	3	.	.	.	.	.	.	1	1	.	7	.	3	165
47.240	201	46	51	.	5	.	3	3	.	1	.	2	.	.	2	1	3	16	.	13	.	1	348
47.242	953	94	18	.	2	2	20	3	.	6	9	.	.	.	.	2	.	8	1	14	.	8	1138
47.244	905	129	16	.	1	7	22	.	2	5	2	.	1	.	.	1	3	12	1	26	2	.	1135
47.246	111	8	6	.	.	1	2	.	.	1	.	.	.	.	.	.	1	12	.	4	.	2	148
47.250	297	18	.	.	.	6	3	.	.	.	1	.	.	.	.	.	.	5	.	15	3	1	349
47.254	245	27	11	.	1	2	8	1	.	3	2	.	.	.	.	1	.	8	.	15	2	.	326
47.258	516	38	6	.	.	.	3	.	.	.	9	.	.	.	.	.	1	6	1	109	37	26	752
47.268	55	15	1	.	.	.	1	.	.	6	72	.	1	.	1	.	1	.	6	29	3	.	191
47.272	21	6	5	.	.	.	.	.	.	2	.	.	.	.	.	.	1	11	1	18	12	9	86
47.276	1935	208	6	.	.	2	45	2	.	3	1	.	.	.	1	.	3	5	2	29	.	.	2242
47.278	54	38	.	.	.	.	6	.	.	.	.	.	1	1	1	.	.	1	2	8	.	.	111
47.280	175	8	3	.	.	2	14	.	.	5	.	.	.	.	.	.	.	1	.	1	.	.	209
47.283	184	6	6	.	.	.	4	.	.	2	.	.	.	.	.	.	.	3	.	5	.	2	212
47.286	1272	15	70	.	.	3	18	1	1	3	.	.	.	1	.	1	.	1	.	12	.	5	1403
47.288	1311	44	17	.	13	2	11	.	.	2	1	.	.	.	.	.	.	2	.	5	1	5	1414
47.290	186	11	93	.	2	3	4	.	.	10	2	.	.	.	2	.	1	.	.	2	.	3	319
47.292	276	30	46	.	6	.	7	4	.	9	2	.	.	.	2	.	.	5	.	9	3	3	402
47.295	702	101	103	1	4	6	7	15	.	8	1	1	1	2	1	.	1	4	2	17	4	4	985
47.297	552	136	64	.	4	16	17	11	.	16	3	1	2	5	.	.	4	13	.	26	1	11	882
47.301	438	54	71	.	5	8	8	10	2	15	2	1	.	.	1	.	3	6	.	8	2	.	634
47.304	92	21	27	.	1	1	4	7	.	9	2	.	2	.	.	.	1	2	.	6	2	3	180
47.306	309	68	70	.	5	16	15	10	2	12	1	.	1	1	1	1	3	13	.	18	4	18	570
47.310	780	154	54	.	9	33	18	51	2	8	10	.	.	2	5	3	2	36	.	42	22	18	1249
47.314	241	83	18	.	6	11	24	14	.	2	.	1	1	2	1	5	4	13	.	24	5	1	456
47.318	73	58	17	.	4	10	23	22	.	2	.	.	.	.	.	2	1	17	.	4	.	15	248
47.322	152	33	14	.	.	5	61	3	3	24	.	.	.	.	.	.	1	13	.	14	11	4	338

APPENDIX TABLE 1.—Counts of fish larvae, tabulated by family, for all stations occupied on the second multivessel EASTROPAC survey (EASTROPAC II).—*Continued.*

STATION NUMBER	Myctophidae	Gonostomatidae	Sternoptychidae	Chauliodontidae	Idiacanthidae	Other Stomiatoidei	Bathylagidae	Paralepididae	Scopelarchidae	Melamphaidae	Bregmacerotidae	Exocoetidae	Trachypteridae	Apogonidae	Bramidae	Chiasmodontidae	Coryphaenidae	Nomeidae	Scombridae	Other identified larvae	Unidentified larvae	Disintegrated larvae	Total fish larvae
47.326	217	40	11	.	.	2	152	15	1	58	.	.	2	.	1	4	.	26	.	50	.	3	582
47.330	436	148	80	.	2	11	137	56	1	14	.	.	.	.	.	12	.	16	.	18	1	15	947
47.334	165	29	32	.	1	9	53	21	.	3	.	.	.	.	.	2	.	4	.	1	.	1	321
47.338	78	19	51	.	.	8	24	8	.	4	.	.	.	.	.	.	.	7	.	.	.	.	199
47.342	302	24	62	3	1	2	19	32	1	8	.	.	.	.	.	4	.	4	.	10	.	.	472
47.345	856	45	78	2	2	11	26	6	.	11	.	.	.	.	.	.	.	15	.	.	.	9	1061
47.349	288	61	49	.	.	5	16	.	1	1	.	.	.	.	.	1	.	2	.	1	.	1	426
47.351	684	66	85	5	1	10	60	3	5	11	.	.	.	.	.	6	.	13	.	2	6	9	966
47.354	71	87	.	.	.	1	.	.	.	.	.	1	.	.	.	.	.	7	.	.	.	1	168
47.357	239	67	27	1	.	4	14	4	5	5	.	.	.	.	1	2	.	15	.	2	2	2	390
47.359	68	56	23	.	.	2	10	1	1	2	.	.	.	.	.	.	.	5	.	.	1	7	176
47.362	81	4	34	11	.	.	3	.	3	1	.	.	.	.	.	.	.	.	.	.	1	1	139
47.364	96	7	4	.	1	.	3	.	.	2	.	.	.	.	.	.	.	3	.	.	.	.	116
47.367	97	24	22	6	1	.	11	.	1	3	.	.	.	.	.	1	.	8	.	3	.	3	180
47.369	13	4	1	.	1	.	3	.	.	1	.	.	.	.	.	.	.	1	.	2	.	.	26
47.371	49	12	1	.	.	1	2	.	.	2	.	.	.	.	.	1	.	.	.	2	.	.	70
47.373	260	239	48	1	3	.	2	3	2	1	1	.	.	.	.	.	.	.	.	16	1	2	579
47.376	52	76	16	3	5	.	9	.	.	5	.	.	.	.	.	.	.	1	.	1	.	5	173
47.379	7	56	9	3	.	.	8	.	.	1	1	.	.	.	2	4	.	.	.	3	1	.	95
47.382	35	114	20	7	3	3	4	.	.	4	4	.	.	.	.	5	.	.	.	1	1	4	205
47.415	30	10	4	.	.	2	.	.	.	.	1	.	.	.	.	.	.	.	.	2	.	.	49
47.430	82	109	7	1	1	1	.	1	.	.	1	.	.	.	.	.	.	.	.	7	.	.	210
47.432	142	101	21	.	3	.	.	2	.	1	2	.	.	.	.	.	.	.	.	2	.	2	276
47.436	10	2	11	.	.	3	2	.	2	1	.	1	.	.	2	.	.	2	.	25	1	2	64
47.438	100	35	14	1	1	3	1	2	.	6	.	.	.	8	1	.	1	11	.	28	2	1	215
47.440	34	109	30	3	.	10	.	1	.	1	.	.	.	1	.	3	.	.	.	12	8	.	212
47.443	56	17	57	.	.	2	1	1	.	3	.	1	.	.	.	.	.	1	.	6	.	1	146
47.446	152	4	2	.	.	1	2	.	.	4	.	.	.	.	.	.	.	.	.	8	.	.	173
47.450	570	85	126	10	.	12	20	41	.	10	.	.	.	.	.	2	.	4	.	41	3	12	936
47.454	200	24	75	1	.	6	41	40	.	6	.	.	.	.	.	3	.	1	.	4	1	5	407
47.458	32	5	6	.	.	3	42	37	.	3	.	.	.	.	.	1	.	1	.	3	.	8	141
47.462	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1
47.466	84	8	3	.	.	3	7	14	.	2	.	.	.	.	.	.	.	.	.	30	.	1	152
47.470	81	110	7	.	.	.	6	4	.	1	.	.	.	.	.	.	.	.	.	5	1	.	215
47.478	38	36	34	.	2	3	6	4	.	1	.	.	.	.	.	3	.	2	.	1	.	.	130
47.486	194	38	29	.	.	1	11	12	.	2	1	.	3	3	1	2	4	7	.	11	1	4	324
47.490	238	24	25	.	1	1	13	20	.	7	.	.	.	2	2	2	1	1	.	7	3	17	364
47.494	77	10	40	.	1	.	2	.	1	7	.	.	.	.	.	.	.	.	.	.	1	2	141
47.498	366	75	111	.	.	7	1	6	2	6	2	.	1	.	.	.	1	.	.	3	5	6	592
47.501	454	165	80	2	2	8	13	.	.	3	.	.	.	.	.	1	3	4	1	7	1	28	772
47.504	628	59	91	1	.	7	20	.	1	4	.	1	.	.	.	.	2	44	.	4	5	28	895
47.507	305	77	33	.	2	6	6	2	.	3	.	9	1	.	.	3	1	3	33	7	1	26	518
47.509	986	65	186	2	2	2	26	.	.	5	.	.	.	.	.	2	.	8	2	10	.	35	1331
47.511	346	2	4	.	2	.	11	.	.	1	.	1	.	.	.	.	.	1	.	3	1	.	372
47.513	80	4	.	.	.	.	.	.	.	3	.	2	1	.	.	.	.	2	.	2	.	.	94
47.515	35	11	14	.	.	.	7	.	.	3	.	.	.	.	.	.	.	2	.	1	1	6	80
47.517	34	36	1	.	.	.	1	.	.	3	.	.	.	.	.	.	.	3	2	4	.	1	85
47.520	55	80	.	.	4	.	3	3	1	6	.	.	.	.	.	.	.	4	.	44	.	1	201
47.523	4	30	.	.	1	.	7	.	1	3	.	.	.	.	.	.	.	3	5	8	.	1	63
47.525	7	10	.	.	.	.	6	.	1	2	3	.	.	.	.	.	1	.	4	13	1	4	52
47.527	550	132	.	.	2	.	3	.	.	3	753	.	.	.	.	.	1	5	25	580	52	12	2118

APPENDIX TABLE 2.—Myctophid larvae, tabulated by genus or species, for all stations occupied on the second multi-vessel EASTROPAC survey (EASTROPAC II).

STATION NUMBER	Diogenichthys laternatus	Lampanyctus spp.	Benthosema panamense	Ceratoscopelus townsendi	Diaphus spp.	Gonichthys tenuiculus	Hygophum atratum	Hygophum proximum	Lampadena spp.	Lepidophanes pyrsobolus	Loweina laurae (rara)	Myctophum aurolaternatum	Myctophum nitidulum	Myctophum spp. (other)	Notolychnus valdiviae	Notoscopelus resplendens	Protomyctophum sp.	Symbolophorus evermanni	Triphoturus spp.	Other identified[1] myctophids	Unidentified myctophids	Disintegrated myctophids	Total myctophids
45.016	2	5	.	1	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	12
45.018	9	10	.	1	.	1	10	1	.	2	.	.	.	.	.	.	.	.	.	.	.	1	35
45.020	10	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.	1	1	.	.	.	.	14
45.021	7	1	.	.	.	.	4	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	13
45.023	13	6	.	.	5	.	35	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.	61
45.024	20	6	.	.	4	2	52	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	86
45.026	27	1	.	.	3	1	4	1	.	2	.	.	.	.	1	.	.	.	.	.	.	.	40
45.028	22	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	24
45.030	9	1	.	.	10	.	7	3	.	.	.	.	.	.	.	.	.	.	.	.	3	1	34
45.032	109	1	.	.	32	1	5	1	.	.	.	3	.	.	.	.	.	4	.	.	1	1	158
45.034	138	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	5	146
45.035	36	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	40
45.037	36	.	.	.	2	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	1	41
45.039	52	.	.	.	12	1	.	.	.	.	.	.	.	.	.	.	.	8	.	.	.	4	77
45.041	22	1	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	29
45.043	14	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	17
45.044	28	1	.	.	19	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	50
45.046	23	1	.	.	16	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	43
45.048	20	.	.	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25
45.050	16	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	19
45.051	70	6	.	.	.	1	.	.	.	.	.	1	.	.	5	.	.	3	1	.	.	.	87
45.053	36	.	.	.	3	.	.	9	.	.	.	.	.	.	9	.	.	16	.	.	.	2	75
45.054	26	.	.	.	.	.	.	2	.	.	.	.	.	.	2	.	.	9	.	.	.	5	44
45.056	7	1	.	.	.	.	.	2	.	.	.	.	1	.	4	.	.	5	1	.	.	1	22
45.058	51	4	.	.	11	.	.	14	.	3	.	1	2	20	8	.	.	21	.	.	2	9	146
45.060	13	1	.	.	13	.	.	12	.	1	.	.	.	.	11	.	1	25	1	.	.	4	82
45.063	.	.	.	.	2	.	.	6	1	.	.	2	.	.	.	.	.	6	1	.	1	10	29
45.065	.	31	.	.	14	.	.	16	.	.	.	7	.	8	7	2	.	2	2	.	.	27	116
45.067	12	46	.	.	35	1	.	17	.	1	3	12	.	31	3	3	.	4	6	.	4	7	185
45.071	5	14	.	.	3	.	.	5	.	.	1	2	.	8	1	2	.	.	.	.	.	1	42
45.073	11	6	.	.	14	.	.	6	.	.	.	2	.	12	1	.	.	.	.	.	2	11	65
45.078	15	33	.	.	7	.	.	5	.	.	.	1	.	7	.	2	.	.	.	.	.	1	71
45.083	23	4	.	.	.	.	.	1	2	.	1	.	.	.	.	.	.	.	.	.	1	5	37
45.086	15	8	.	.	.	.	.	2	1	.	.	.	9	12	5	2	.	2	1	.	.	8	65
45.090	16	5	.	.	.	.	.	4	.	.	.	1	7	1	.	.	.	2	.	.	1	10	47
45.094	42	28	.	.	1	.	2	15	.	.	.	.	28	.	.	.	.	.	.	.	.	34	150
45.098	15	1	.	.	1	.	1	3	.	.	.	3	12	.	.	.	.	.	.	.	2	5	43
45.102	20	48	.	.	7	4	.	16	.	.	2	.	18	.	.	.	.	.	2	.	.	19	136
45.106	166	10	.	.	2	1	1	13	.	.	2	.	55	1	.	3	.	1	.	.	2	8	265
45.110	298	38	.	.	9	1	9	116	.	.	.	2	51	.	5	.	2	4	2	3	1	4	545
45.114	13	9	.	.	.	.	.	.	.	.	.	.	10	.	1	.	.	.	.	.	.	7	40
45.117	53	6	.	.	1	.	.	4	.	.	.	.	2	.	8	.	.	1	.	.	.	17	92
45.121	25	16	.	.	.	.	1	1	.	1	.	.	.	.	1	.	.	.	1	.	.	9	55
45.125	.	19	.	.	.	.	1	2	.	1	2	1	.	.	6	1	.	2	1	.	1	4	41
45.127	.	9	.	.	.	.	.	2	.	.	1	.	.	.	1	1	.	.	2	.	5	.	21
45.129	.	8	.	.	.	.	.	3	.	1	.	.	.	.	4	.	.	1	1	.	4	.	22
45.131	.	26	.	.	8	1	.	3	.	.	.	.	.	.	14	.	.	7	.	.	1	13	73
45.133	.	21	.	145	35	.	.	42	.	26	.	.	.	3	4	.	.	13	2	.	7	25	323
45.135	.	8	.	77	20	.	.	30	1	.	.	.	.	1	.	2	.	12	1	2	6	5	165
45.137	.	1	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	3	5	11
45.139	.	3	.	2	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	16	.	24
45.140	.	25	.	26	15	.	.	5	1	.	.	.	.	.	2	.	.	27	.	.	.	5	106

APPENDIX TABLE 2.—Myctophid larvae, tabulated by genus or species, for all stations occupied on the second multi-vessel EASTROPAC survey (EASTROPAC II).—*Continued.*

STATION NUMBER	Diogenichthys laternatus	Lampanyctus spp.	Benthosema panamense	Ceratoscopelus townsendi	Diaphus spp.	Gonichthys tenuiculus	Hygophum atratum	Hygophum proximum	Lampadena spp.	Lepidophanes pyrosebolus	Loweina lauraae (rara)	Myctophum aurolaternatum	Myctophum nitidulum	Myctophum spp. (other)	Notolychnus valdiviae	Notoscopelus resplendens	Protomyctophum sp.	Symbolophorus evermanni	Triphoturus spp.	Other identified[1] myctophids	Unidentified myctophids	Disintegrated myctophids	Total myctophids
45.163	.	1	.	5	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1	8
45.165	.	23	.	48	20	.	.	36	.	.	.	1	.	7	4	.	.	6	.	1	2	4	152
45.167	.	6	.	43	2	.	.	15	.	.	.	.	.	1	.	.	.	7	.	.	.	12	86
45.169	.	7	.	9	7	.	.	17	.	.	.	.	.	7	1	.	.	1	.	.	.	7	56
45.171	.	5	.	5	5	.	.	.	.	1	.	.	.	1	2	.	.	2	.	.	2	3	26
45.173	.	1	.	.	.	.	.	9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10
45.175	32	12	.	3	.	.	.	11	.	.	.	.	.	.	.	.	.	2	.	.	.	2	62
45.177	23	43	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.	.	70
45.179	39	12	.	.	.	.	.	2	.	.	.	1	.	.	.	.	.	.	.	.	.	5	59
45.183	14	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	7	26
45.187	244	8	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2	.	.	.	255
45.191	115	13	.	.	.	.	1	2	.	.	.	.	.	1	.	2	.	2	3	.	.	5	144
45.194	27	3	.	.	.	.	.	3	.	.	.	.	.	4	.	.	.	.	2	.	.	10	49
45.198	116	35	.	.	1	.	10	3	.	.	.	.	44	.	1	.	1	.	1	.	.	39	251
45.202	10	24	.	.	1	.	.	.	.	.	.	.	16	.	.	1	.	.	.	.	.	1	53
45.206	4	10	.	.	.	.	.	.	.	.	.	.	3	1	.	.	.	.	.	.	.	4	22
45.283	26	56	.	.	.	.	.	.	.	.	.	.	14	.	.	.	.	.	.	.	1	5	102
45.287	.	22	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	25
45.289	68	74	.	.	.	.	1	.	.	1	1	3	1	.	.	3	.	.	.	.	.	5	157
45.293	127	13	.	.	.	.	1	1	.	.	.	.	5	1	1	3	.	4	.	1	.	.	157
45.297	163	18	.	.	4	.	.	1	.	5	1	1	8	12	8	.	.	7	.	.	.	5	231
45.301	8	5	.	.	5	.	.	.	.	.	.	1	.	2	1	.	.	.	.	1	2	1	24
45.305	15	29	.	.	30	.	.	18	.	.	.	2	2	.	12	2	.	2	3	.	.	4	119
45.309	10	6	.	.	.	.	2	1	.	3	.	.	.	2	4	.	.	13	.	1	1	1	44
45.313	33	.	.	.	.	.	3	1	.	.	1	.	1	.	.	.	.	2	.	2	.	6	49
45.316	10	2	.	.	9	.	.	3	.	2	.	5	.	2	.	1	.	.	2	.	1	4	41
45.319	14	.	.	.	4	.	.	4	.	.	.	2	1	3	1	.	.	.	.	.	1	2	32
45.321	19	.	.	.	2	.	.	.	1	2	.	1	4	2	5	.	.	1	.	.	.	8	45
45.323	32	.	.	.	.	.	.	3	.	.	.	1	.	.	1	.	.	11	.	.	.	3	51
45.325	967	29	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	3	.	.	.	.	1002
45.329	49	16	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	69
45.331	218	13	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	235
45.333	84	12	.	.	9	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	1	108
45.335	47	.	.	.	16	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	65
45.337	37	1	.	.	4	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	49
45.339	9	.	.	.	15	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	26
45.341	17	2	.	.	26	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	47
45.343	6	.	.	.	9	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	17
45.344	3	1	.	.	15	.	1	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	21
45.346	6	2	.	.	10	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	19
45.348	12	5	.	.	9	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	30
45.350	39	1	.	.	25	.	3	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	70
45.352	17	.	.	.	4	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	29
45.356	40	.	.	.	24	.	1	.	.	.	.	4	.	.	.	.	.	.	.	.	.	.	69
45.358	46	.	.	.	49	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	98
45.360	9	1	.	.	5	.	1	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	18
45.362	1	.	5	.	26	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	3	36
45.365	.	.	58	.	39	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	99
45.367	5	.	.	.	12	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	5	23
45.369	53	2	9	.	34	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	101
45.371	32	1	.	.	50	.	28	.	.	.	.	5	.	.	.	.	.	.	.	.	1	3	120
45.373	59	1	.	.	36	.	20	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	117

APPENDIX TABLE 2.—Myctophid larvae, tabulated by genus or species, for all stations occupied on the second multivessel EASTROPAC survey (EASTROPAC II).—*Continued.*

STATION NUMBER	Diogenichthys laternatus	Lampanyctus spp.	Benthosema panamense	Ceratoscopelus townsendi	Diaphus spp.	Gonichthys tenuiculus	Hygophum atratum	Hygophum proximum	Lampadena spp.	Lepidophanes pyrsobolus	Loweina laurae (rara)	Myctophum aurolaternatum	Myctophum nitidulum	Myctophum spp. (other)	Notolychnus valdiviae	Notoscopelus resplendens	Protomyctophum sp.	Symbolophorus evermanni	Triphoturus spp.	Other identified[1] myctophids	Unidentified myctophids	Disintegrated myctophids	Total myctophids
45.375	20	.	.	.	8	.	2	.	.	.	.	1	.	.	.	.	.	.	.	.	1	2	34
45.377	42	.	.	.	22	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	67
45.379	42	8	.	.	63	.	85	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	199
45.381	59	.	.	.	13	.	19	.	.	.	.	5	.	.	.	.	.	.	.	.	.	2	98
45.383	37	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	40
45.385	7	.	.	.	1	.	7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	19
45.387	6	12	.	.	2	.	2	.	.	.	.	.	.	.	.	.	.	.	1	.	1	2	26
CRUISE	46																						
46.002	.	.	.	.	12	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	14
46.004	7	1	.	.	94	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	103
46.006	2	.	.	.	27	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	30
46.007	1	.	.	.	9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10
46.009	.	1	.	.	16	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	17
46.011	26	.	.	.	33	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	60
46.013	31	2	.	.	55	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	89
46.015	1	.	.	.	17	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	18
46.017	1	.	.	.	23	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25
46.019	114	4	.	.	163	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	1	285
46.020	75	3	.	.	76	.	.	.	.	.	.	2	.	.	.	.	.	3	.	.	.	1	160
46.022	38	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	38
46.024	60	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	64
46.026	150	53	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	206
46.028	343	32	.	.	30	3	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	3	412
46.030	80	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	1	.	.	.	3	85
46.032	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	1	1	9
46.034	117	8	.	.	6	1	.	.	.	.	.	.	2	.	11	.	.	5	.	.	1	1	152
46.036	357	20	.	.	.	.	.	.	.	.	.	3	2	.	36	.	.	14	1	.	.	3	436
46.038	12	1	.	.	.	.	.	.	.	.	.	.	1	.	3	.	.	1	.	.	1	1	20
46.040	19	2	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	2	.	25
46.042	31	1	.	.	2	.	.	3	2	8	.	4	.	1	2	.	1	4	2	.	1	.	62
46.044	69	3	.	.	6	.	.	.	.	.	.	.	.	.	3	.	.	4	.	.	.	4	89
46.046	51	1	.	.	16	.	.	.	3	1	.	2	.	1	.	.	.	.	.	.	.	3	78
46.048	50	1	.	.	5	.	.	1	.	.	1	.	.	3	.	.	.	1	1	.	.	.	63
46.050	163	13	.	.	8	.	.	14	1	2	.	4	4	12	8	.	1	9	2	1	.	8	250
46.052	207	21	.	.	5	.	2	9	.	10	1	3	2	23	13	2	1	9	.	.	11	.	319
46.054	126	23	.	.	.	.	.	1	.	.	.	3	5	11	16	1	.	15	.	.	.	10	211
46.055	65	15	.	.	.	2	1	.	.	.	2	.	4	1	6	.	.	1	.	.	.	3	100
46.057	366	241	.	.	4	11	3	17	.	17	2	8	31	.	5	13	.	8	22	.	3	.	751
46.059	133	250	.	.	.	9	11	.	.	8	.	5	10	3	6	16	.	3	17	.	3	20	494
46.061	71	36	.	.	.	1	.	.	.	.	.	.	11	.	1	2	.	.	1	.	.	25	148
46.063	14	27	.	.	.	.	.	.	.	.	.	.	4	.	.	.	.	.	.	.	.	3	48
46.065	189	84	.	.	7	5	18	14	.	.	1	.	56	.	.	24	.	1	3	.	.	2	404
46.067	164	73	.	.	3	.	7	4	.	.	.	.	7	.	.	3	1	.	1	.	3	3	269
46.069	46	64	.	.	2	.	.	1	.	.	.	1	2	.	.	.	.	.	.	.	.	.	116
46.071	21	34	.	.	2	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.	1	10	72
46.075	19	14	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.	35
46.077	30	6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	36
46.079	285	28	.	.	4	21	.	.	.	.	.	2	18	.	.	33	.	1	13	.	1	2	408
46.082	35	2	.	.	1	6	.	.	.	.	.	1	4	.	.	5	.	.	.	.	5	2	61

APPENDIX TABLE 2.—Myctophid larvae, tabulated by genus or species, for all stations occupied on the second multi-vessel EASTROPAC survey (EASTROPAC II).—*Continued.*

STATION NUMBER	Diogenichthys laternatus	Lampanyctus spp.	Benthosema panamense	Ceratoscopelus townsendi	Diaphus spp.	Gonichthys tenuiculus	Hygophum atratum	Hygophum proximum	Lampadena spp.	Lepidophanes pyrsobolus	Loweina laurae (rara)	Myctophum aurolaternatum	Myctophum nitidulum	Myctophum spp. (other)	Notolychnus valdiviae	Notoscopelus resplendens	Protomyctophum sp.	Symbolophorus evermanni	Triphoturus spp.	Other identified[1] myctophids	Unidentified myctophids	Disintegrated myctophids	Total myctophids
46.084	23	9	.	.	.	.	.	.	.	.	.	1	3	.	.	5	.	.	.	.	4	.	45
46.086	68	20	.	.	.	3	.	.	.	1	.	2	2	.	.	4	.	.	1	.	.	1	102
46.088	69	23	.	.	.	2	.	.	.	.	.	6	3	.	.	16	.	2	.	.	.	3	124
46.090	72	10	.	.	5	1	.	.	.	.	1	.	2	.	.	1	.	.	.	.	.	7	99
46.092	88	4	.	.	1	.	.	.	.	1	.	.	1	.	.	2	.	.	2	.	1	.	100
46.094	196	25	.	.	8	1	.	.	.	3	.	5	13	3	25	3	1	1	9	1	4	2	300
46.096	144	37	.	.	9	.	.	4	.	8	.	8	4	7	6	1	.	3	8	.	1	.	240
46.098	50	.	.	.	1	.	.	3	.	.	.	1	3	5	3	1	.	3	1	.	.	2	73
46.100	105	.	.	.	3	.	.	.	.	.	.	.	.	5	4	6	.	.	2	.	.	.	125
46.102	273	27	.	.	.	3	.	1	.	.	.	3	1	.	10	.	5	7	.	.	1	3	334
46.104	70	15	.	.	.	.	.	.	.	.	.	2	2	.	15	.	.	1	.	.	1	3	109
46.106	110	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	115
46.108	241	8	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	250
46.110	151	10	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	162
46.112	530	13	.	.	16	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	1	.	562
46.114	12	.	.	.	16	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	31
46.116	9	.	.	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	14
46.118	50	6	.	.	111	1	1	.	.	.	.	7	.	.	.	.	.	.	.	.	.	.	176
46.120	19	.	.	.	56	.	.	.	.	.	.	5	.	.	.	.	.	.	.	.	.	.	80
46.122	.	.	.	.	11	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	3	2	17
46.124	.	.	.	.	19	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	19
46.126	11	4	.	.	46	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	63
46.128	1	1	.	.	97	.	.	.	.	.	.	6	.	.	.	.	.	.	.	.	6	2	113
46.130	9	.	.	.	37	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	46
46.132	3	1	.	.	22	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	26
46.134	2	.	7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9
46.135	.	.	81	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	81
46.137	201	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	201
46.139	160	14	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	175
46.141	435	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	438
46.143	112	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	113
46.145	269	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	1	282
46.147	480	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	484
46.149	1328	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1333
46.151	1358	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1358
46.153	2505	49	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	3	2561
46.155	939	20	.	.	1	5	.	.	.	.	.	3	.	.	1	.	.	4	.	.	.	.	973
46.157	474	3	.	.	.	2	.	.	.	.	.	3	1	.	4	.	.	1	.	.	1	1	490
46.159	59	1	.	.	4	2	.	.	.	.	.	.	1	.	1	.	1	.	1	.	1	.	71
46.161	268	17	.	.	.	3	.	1	.	.	2	3	2	.	39	2	.	3	6	1	3	.	350
46.163	214	28	.	.	1	4	.	1	.	3	.	3	2	.	12	.	5	7	4	.	1	5	290
46.165	48	7	.	.	.	.	.	1	.	11	1	5	4	.	6	1	.	4	.	.	1	1	90
46.167	131	25	.	.	.	.	.	.	.	.	.	23	5	.	3	3	.	2	.	.	1	2	195
46.169	89	34	.	.	2	2	.	.	.	.	1	.	3	.	3	13	1	6	1	.	4	4	163
46.171	182	8	.	.	1	1	.	.	.	.	.	.	30	.	.	14	.	3	5	.	.	11	255
46.173	27	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	.	33
46.175	44	4	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	2	52
46.177	105	8	.	.	1	.	.	.	.	.	.	.	1	.	.	4	.	1	5	.	.	.	124
46.179	182	14	.	.	1	.	.	.	.	.	.	.	1	.	.	6	1	1	3	.	.	4	213
46.181	20	5	.	.	1	1	.	.	.	.	.	.	5	.	.	.	.	1	2	.	17	.	52
46.183	50	9	.	.	4	1	1	.	.	.	.	.	9	.	.	4	.	1	6	.	.	.	85
46.185	178	36	.	.	8	2	.	.	.	.	.	2	8	.	.	11	.	4	11	.	1	1	262

APPENDIX TABLE 2.—Myctophid larvae, tabulated by genus or species, for all stations occupied on the second multivessel EASTROFAC survey (EASTROPAC II).—*Continued.*

STATION NUMBER	Diogenichthys laternatus	Lampanyctus spp.	Benthosema panamense	Ceratoscopelus townsendi	Diaphus spp.	Gonichthys tenuiculus	Hygophum atratum	Hygophum proximum	Lampadena spp.	Lepidophanes pyrsobolus	Loweina laurae (rara)	Myctophum aurolaternatum	Myctophum nitidulum	Myctophum spp. (other)	Notolychnus valdiviae	Notoscopelus resplendens	Protomyctophum sp.	Symbolophorus evermanni	Triphoturus spp.	Other identified[1] myctophids	Unidentified myctophids	Disintegrated myctophids	Total myctophids
46.187	468	40	.	.	.	.	.	.	.	.	.	2	1	.	.	.	.	2	2	.	.	1	516
46.189	234	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	236
CRUISE	47																						
47.001	68	13	.	.	8	2	.	.	.	.	.	2	1	.	.	1	.	1	1	.	.	.	97
47.005	161	33	9	.	33	1	.	.	.	.	.	19	6	.	.	.	.	17	1	.	.	7	287
47.008	205	31	5	.	4	2	.	.	.	.	.	4	.	.	.	.	.	3	1	.	.	2	257
47.011	117	22	13	.	2	.	.	.	.	.	.	3	.	.	.	.	.	3	1	.	.	.	161
47.019	287	37	2	.	39	.	.	.	.	.	.	1	.	.	.	.	.	2	2	.	.	.	370
47.022	148	11	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	1	2	.	5	.	169
47.025	73	5	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	2	83
47.028	175	66	.	.	5	1	.	.	.	.	.	7	.	.	.	.	.	9	.	.	1	.	264
47.032	148	38	.	.	12	.	.	.	.	.	.	3	.	.	.	.	.	6	1	.	.	.	208
47.034	95	23	.	.	.	1	.	.	.	.	.	7	4	.	.	.	.	6	.	.	.	3	139
47.035	171	21	.	.	1	3	.	.	.	.	.	9	12	.	.	.	.	3	1	.	1	1	223
47.040	129	38	11	.	3	.	.	.	.	.	.	10	6	.	.	.	.	.	.	.	6	2	205
47.049	42	9	.	.	1	.	.	.	.	.	.	4	3	.	.	.	.	1	2	.	1	1	64
47.053	105	89	.	.	1	4	.	.	.	.	.	19	18	.	.	11	.	2	3	.	9	4	265
47.057	192	50	.	.	.	1	.	.	.	.	.	23	1	.	.	6	.	1	12	.	11	3	300
47.061	22	12	.	.	3	2	.	.	.	.	.	4	23	.	.	1	.	.	9	.	.	3	79
47.065	31	22	.	.	1	3	.	.	.	.	.	2	12	.	.	.	.	.	22	.	.	6	99
47.069	29	6	.	.	2	3	.	.	.	.	.	.	35	.	.	28	.	2	5	.	30	.	140
47.070	50	11	.	.	.	.	.	.	.	.	.	1	17	.	.	.	.	1	10	.	.	.	90
47.074	98	4	.	.	1	1	.	.	.	.	.	.	26	.	.	1	.	.	5	.	2	.	138
47.078	5	.	.	.	1	.	.	.	.	.	.	.	3	.	.	.	.	.	2	.	.	.	11
47.082	70	10	.	.	.	.	.	.	.	.	.	.	11	.	.	.	.	.	6	.	15	7	119
47.086	212	10	.	.	.	.	.	.	.	.	.	.	6	.	.	.	.	.	18	.	1	1	248
47.090	33	17	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	2	.	.	3	57
47.094	96	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	1	100
47.097	9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	6	16
47.099	6	7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	16
47.101	39	6	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	2	48
47.103	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2
47.105	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
47.107	30	70	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	6	.	.	1	109
47.109	1	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	6
47.113	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
47.124	.	7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	10
47.128	.	31	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.	35
47.132	15	53	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	12	.	.	3	85
47.134	5	10	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	1	1	.	1	1	21
47.137	4	4	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	2	3	1	1	17
47.139	3	7	.	.	.	.	.	.	.	1	.	.	.	.	1	.	.	3	1	.	.	.	16
47.141	12	5	.	.	.	.	2	1	.	.	.	.	.	.	.	.	.	1	1	.	1	1	24
47.143	19	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	23
47.145	.	2	.	.	.	.	6	.	.	.	.	1	.	.	.	2	.	1	1	.	2	.	15
47.147	2	2	.	.	.	.	16	.	.	.	1	4	.	.	.	1	.	3	8	5	1	1	44
47.149	12	7	.	.	.	.	10	.	.	.	.	.	1	.	.	.	.	.	6	.	3	1	40
47.151	6	1	.	.	.	.	5	3	.	.	.	1	.	.	.	.	.	1	4	.	.	1	22
47.153	6	3	.	.	.	1	11	.	.	.	.	1	.	.	.	.	.	1	3	.	3	1	30

APPENDIX TABLE 2.—Myctophid larvae, tabulated by genus or species, for all stations occupied on the second multi-vessel EASTROPAC survey (EASTROPAC II).—*Continued.*

STATION NUMBER	Diogenichthys laternatus	Lampanyctus spp.	Benthosema panamense	Ceratoscopelus townsendi	Diaphus spp.	Gonichthys tenuiculus	Hygophum atratum	Hygophum proximum	Lampadena spp.	Lepidophanes pyrsobolus	Loweina laurae (rara)	Myctophum aurolaternatum	Myctophum nitidulum	Myctophum spp. (other)	Notolychnus valdiviae	Notoscopelus resplendens	Protomyctophum sp.	Symbolophorus evermanni	Triphoturus spp.	Other identified[1] myctophids	Unidentified myctophids	Disintegrated myctophids	Total myctophids
47.155	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
47.157	72	8	.	.	.	.	16	.	.	.	.	.	1	.	1	.	.	2	6	.	3	.	109
47.159	9	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	2	1	17
47.162	.	2	.	.	.	.	5	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.	11
47.164	9	7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	.	4	.	25
47.166	11	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	7	.	6	.	28
47.168	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	6
47.171	50	12	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	3	.	.	.	66
47.173	179	35	.	.	.	.	.	.	.	.	.	2	4	.	.	.	.	.	30	.	1	.	251
47.175	265	15	.	.	.	.	.	.	.	.	.	.	9	.	.	.	.	1	37	.	.	.	327
47.177	60	13	.	.	.	.	.	.	.	.	.	1	13	.	.	.	.	1	27	.	.	4	119
47.179	190	4	.	.	.	1	.	.	.	.	.	.	4	.	.	.	.	.	21	.	.	8	228
47.181	126	6	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	1	12	.	1	2	150
47.185	281	16	.	.	.	2	.	.	.	.	.	.	13	.	.	3	.	1	34	.	.	.	350
47.189	20	.	.	.	.	2	.	.	.	.	.	.	2	.	.	.	.	.	4	.	.	.	28
47.193	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
47.197	56	.	.	.	.	2	.	.	.	.	.	.	28	.	.	.	.	.	10	.	.	1	97
47.201	148	75	.	.	11	1	.	.	.	.	.	.	89	.	.	4	.	8	38	.	2	16	392
47.205	51	28	.	.	1	1	.	.	.	.	.	.	19	.	.	.	.	.	3	.	.	6	109
47.213	595	121	.	.	5	2	.	.	.	.	.	14	6	.	.	4	1	.	9	.	.	12	769
47.217	360	36	.	.	3	3	.	.	.	.	.	19	4	.	.	5	.	.	6	.	1	3	440
47.221	425	6	.	.	.	.	.	.	.	.	.	5	6	.	2	.	.	.	3	.	.	5	452
47.225	416	54	.	.	2	5	.	.	.	2	.	15	8	.	1	.	.	3	6	.	.	.	512
47.229	265	145	.	.	3	6	.	.	.	.	.	30	10	.	4	.	.	20	4	.	6	3	496
47.233	1206	146	.	.	12	6	.	.	.	.	.	23	.	.	3	1	.	33	2	.	2	7	1441
47.237	86	5	.	.	2	2	.	.	.	.	.	5	.	.	.	.	.	.	.	.	.	.	100
47.240	182	8	.	.	4	2	.	.	.	.	.	4	.	.	1	.	.	.	.	.	.	.	201
47.242	931	16	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	953
47.244	837	58	.	.	2	2	.	.	.	.	.	3	.	.	.	.	.	2	.	.	1	.	905
47.246	103	6	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	111
47.250	295	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	297
47.254	224	3	.	.	17	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	245
47.258	11	19	402	.	67	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	12	3	516
47.268	55	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	55
47.272	21	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	21
47.276	1904	17	.	.	13	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1935
47.278	45	8	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	54
47.280	170	3	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	175
47.283	177	7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	184
47.286	1260	10	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1272
47.288	1297	10	.	.	.	1	1	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	1311
47.290	172	6	.	.	.	.	.	.	.	.	1	4	.	.	.	.	.	2	.	.	.	1	186
47.292	266	4	.	.	.	.	.	.	.	.	.	3	.	.	1	.	.	.	1	.	.	1	276
47.295	627	28	.	.	.	2	.	.	.	.	.	8	1	.	13	.	.	16	.	1	2	4	702
47.297	432	51	.	.	.	2	.	.	.	.	.	12	4	.	17	.	.	27	2	.	.	5	552
47.301	382	25	.	.	.	8	.	.	.	.	.	7	.	.	6	.	.	10	.	.	.	.	438
47.304	56	16	.	.	.	.	.	.	.	.	.	4	2	.	4	.	1	7	1	.	.	1	92
47.306	241	16	.	.	.	3	.	.	.	.	.	19	5	.	11	.	.	13	.	.	.	1	309
47.310	552	116	.	.	.	5	.	.	.	1	.	44	3	.	11	.	.	19	4	.	16	9	780
47.314	145	62	.	.	.	.	.	.	.	1	.	18	2	.	1	4	.	2	3	.	5	.	241
47.318	49	8	.	.	.	.	.	.	.	.	.	4	6	.	.	.	.	2	1	.	.	3	73
47.322	111	11	.	.	2	1	.	.	.	.	.	2	19	.	.	2	.	.	3	.	1	.	152

APPENDIX TABLE 2.—Myctophid larvae, tabulated by genus or species, for all stations occupied on the second multi-vessel EASTROPAC survey (EASTROPAC II).—*Continued.*

STATION NUMBER	Diogenichthys laternatus	Lampanyctus spp.	Benthosema panamense	Ceratoscopelus townsendi	Diaphus spp.	Gonichthys tenuiculus	Hygophum atratum	Hygophum proximum	Lampadena spp.	Lepidophanes pyrsobolus	Loweina laurae (rara)	Myctophum aurolaternatum	Myctophum nitidulum	Myctophum spp. (other)	Notolychnus valdiviae	Notoscopelus resplendens	Protomyctophum sp.	Symbolophorus evermanni	Triphoturus spp.	Other Identified myctophids	Unidentified myctophids	Disintegrated myctophids	Total myctophids
47.326	60	42	.	.	16	3	3	.	.	.	1	2	52	.	.	5	.	.	20	.	11	2	217
47.330	193	53	.	.	13	20	.	.	.	.	.	.	72	.	.	30	.	2	51	.	2	.	436
47.334	92	10	.	.	6	2	.	.	.	.	.	1	19	.	.	13	.	4	16	.	1	1	165
47.338	42	15	.	.	.	1	.	.	.	.	.	1	2	.	.	.	.	.	16	.	.	1	78
47.342	227	8	.	.	.	2	.	.	.	.	.	2	57	.	.	1	.	.	5	.	.	.	302
47.345	813	15	.	.	.	1	.	.	.	.	.	1	12	.	.	2	.	1	8	.	.	3	856
47.349	271	2	.	.	1	2	.	.	.	.	.	2	5	.	.	.	.	2	3	.	.	.	288
47.351	662	7	.	.	1	5	.	.	.	.	.	.	5	.	.	.	.	4	.	.	.	.	684
47.354	1	66	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	1	.	.	2	71
47.357	179	21	.	.	.	8	.	.	.	.	.	12	1	.	.	.	.	14	3	.	.	1	239
47.359	60	3	.	.	1	2	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	68
47.362	69	2	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	1	2	81
47.364	76	7	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	7	.	2	2	96
47.367	71	12	.	.	.	.	1	.	.	.	.	.	.	.	1	.	.	.	7	.	4	1	97
47.369	11	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	.	.	13
47.371	31	4	.	.	.	.	4	.	.	.	.	.	.	.	1	1	.	.	5	3	.	.	49
47.373	155	15	.	.	3	.	44	23	.	.	.	1	.	.	1	2	.	7	2	1	.	6	260
47.376	32	3	.	.	.	.	3	.	.	.	.	1	1	.	4	.	.	3	4	.	.	1	52
47.379	3	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	1	7
47.382	5	2	.	.	.	.	4	.	.	.	.	.	4	.	5	.	.	6	1	.	7	1	35
47.415	6	4	.	.	5	.	.	1	.	.	.	.	.	.	2	1	.	7	.	.	4	.	30
47.430	3	23	.	.	.	.	1	6	.	.	.	.	.	.	4	2	.	35	.	.	8	.	82
47.432	.	34	.	24	12	.	7	14	.	2	.	.	.	.	1	1	1	29	.	5	10	2	142
47.436	5	1	.	.	.	1	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	1	10
47.438	31	49	.	.	.	1	.	.	.	.	.	4	.	.	.	.	.	14	.	.	.	1	100
47.440	10	9	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	10	.	.	2	1	34
47.443	54	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	56
47.446	139	1	.	.	.	4	.	.	.	.	.	4	.	.	.	.	.	2	2	.	.	.	152
47.450	500	19	.	.	.	6	.	.	.	.	.	5	3	.	.	1	.	17	11	.	2	6	570
47.454	153	25	.	.	1	2	.	.	.	.	.	2	1	.	.	2	.	4	9	.	.	1	200
47.458	10	7	.	.	3	1	.	.	.	.	.	1	.	.	.	3	.	.	5	.	.	2	32
47.462	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
47.466	60	5	.	.	2	1	.	.	.	.	.	.	4	.	1	6	.	1	4	.	.	.	84
47.470	39	16	.	.	3	.	.	.	.	.	.	.	14	.	.	2	.	.	6	.	1	.	81
47.478	19	10	.	.	.	.	.	1	.	.	.	4	.	.	1	1	.	.	1	.	1	.	38
47.486	150	12	.	.	.	1	.	1	.	1	2	1	1	.	9	2	.	2	3	.	.	9	194
47.490	199	.	.	.	.	2	.	.	.	2	.	5	2	.	5	5	.	.	6	.	.	12	238
47.494	63	4	.	.	.	.	.	.	.	.	.	1	.	.	3	.	1	.	1	.	.	4	77
47.498	296	16	.	.	1	2	.	.	.	2	.	2	4	.	13	1	8	12	2	.	.	7	366
47.501	401	33	.	.	.	3	.	.	.	.	.	5	2	.	.	.	1	3	.	.	.	6	454
47.504	568	15	.	.	.	1	1	.	.	.	3	6	.	.	9	.	1	3	.	.	.	21	628
47.507	272	23	.	.	.	4	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	3	305
47.509	955	24	.	.	.	3	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	2	986
47.511	344	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	346
47.513	80	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	80
47.515	34	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	35
47.517	32	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	34
47.520	26	9	.	.	18	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	55
47.523	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
47.525	1	1	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	7
47.527	.	.	524	.	24	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	550

APPENDIX TABLE 3.—Counts of selected categories of fish larvae, tabulated by station, EASTROPAC II.

STATION NUMBER	Vinciguerria spp.	Cyclothone spp.	Bathylagus nigrigenys	Leuroglossus stilbius urotranus	Nansenia sp.	Diplophos taenia	Ichthyococcus irregularis	Maurolicus muelleri	Astronesthidae	Bathophilus filifer	Stomias sp.	Evermannellidae	Macroparalepis macrurus	Scopelosauridae	Scomberesocidae	Gempylus serpens	Nealotus tripes	Diplospinus multistriatus	Trichiurus lepturus	Tetragonurus spp.	Trachichthyidae	Balistidae	Ostraciontidae	Total; selected categories
45.016	12	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	14
45.018	77	6	.	.	.	2	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	87
45.020	5	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.	7
45.021	15	1	.	.	.	1	.	.	.	4	1	.	1	.	.	2	.	.	.	.	.	.	.	25
45.023	101	5	.	.	.	.	.	.	.	2	1	1	.	.	.	.	.	.	.	.	.	.	.	110
45.024	95	1	.	.	.	.	.	.	.	.	1	.	.	.	.	2	.	1	.	.	.	.	.	100
45.026	27	.	4	.	.	3	.	.	.	.	.	.	1	.	.	1	.	1	.	.	.	.	1	38
45.028	21	.	9	.	.	1	.	.	.	3	1	.	.	.	.	1	.	.	.	.	.	.	.	36
45.030	54	1	.	.	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	61
45.032	108	.	7	.	.	3	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	10	129
45.034	35	.	1	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	39
45.035	27	.	2	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	34
45.037	24	.	10	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	35
45.039	77	3	1	.	.	2	.	.	.	2	.	.	1	.	.	1	3	.	.	.	.	.	.	90
45.041	49	.	8	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	58
45.043	16	.	5	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	23
45.044	38	1	4	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	45
45.046	56	.	2	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	59
45.048	21	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	23
45.050	2	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
45.051	8	5	4	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	19
45.053	7	12	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	22
45.054	2	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
45.056	4	2	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	8
45.058	11	4	1	.	.	3	.	.	.	.	.	3	1	.	.	1	.	.	.	.	.	.	.	24
45.060	1	5	1	.	.	.	.	.	3	2	.	.	.	.	.	2	.	.	.	.	.	.	.	12
45.063	43	2	1	.	.	1	.	.	.	7	.	2	1	.	.	1	.	.	.	.	.	.	.	58
45.065	368	5	.	.	.	1	.	.	.	12	4	4	3	.	.	.	.	.	.	.	.	.	.	397
45.067	560	23	3	.	.	1	.	.	1	39	6	24	28	.	.	.	.	.	.	.	.	.	.	685
45.071	39	1	.	.	.	.	.	.	.	1	1	4	1	.	.	.	.	.	.	.	.	.	.	47
45.073	65	3	2	.	.	.	.	.	.	.	.	1	1	.	.	.	1	.	.	.	.	.	.	73
45.078	105	1	1	.	.	1	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	110
45.083	26	.	.	.	1	.	.	.	.	.	1	.	2	.	.	.	.	.	.	.	.	.	.	30
45.086	77	.	3	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	81
45.090	65	2	8	.	.	.	.	.	.	3	.	5	.	.	.	.	.	.	.	1	.	.	.	84
45.094	100	7	6	.	.	.	.	.	1	.	1	.	1	.	.	.	.	.	.	.	.	.	.	116
45.098	15	.	2	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	18
45.102	78	4	1	.	.	.	.	.	.	2	.	.	.	.	.	.	1	.	.	.	.	.	.	86
45.106	21	.	5	.	1	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	28
45.110	27	5	12	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	47
45.114	15	5	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22
45.117	43	5	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	52
45.121	91	7	4	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	104
45.125	301	24	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	327
45.127	38	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	41
45.129	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
45.131	325	12	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	339
45.133	3	30	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	.	.	.	.	.	.	36
45.135	6	10	.	.	.	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	18
45.137	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
45.139	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
45.140	12	36	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	52

APPENDIX TABLE 3.—Counts of selected categories of fish larvae, tabulated by station, EASTROPAC II.—*Continued.*

STATION NUMBER	Vinciguerria spp.	Cyclothone spp.	Bathylagus nigrigenys	Leuroglossus stilbius urotranus	Nansenia sp.	Diplophos taenia	Ichthyococcus irregularis	Maurolicus muelleri	Astronesthidae	Buthophilus filifer	Stomias sp.	Evermannellidae	Macroparalepis macrurus	Scopelosauridae	Scomberesocidae	Gempylus serpens	Nealotus tripes	Diplospinus multistriatus	Trichiurus lepturus	Tetragonurus spp.	Trachichthyidae	Balistidae	Ostraciontidae	Total: selected categories
45.163	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
45.165	33	29	.	.	.	2	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	66
45.167	3	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6
45.169	5	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	15
45.171	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
45.173	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
45.175	20	7	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	28
45.177	141	7	.	.	1	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	151
45.179	32	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	33
45.183	13	1	4	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.	.	20
45.187	13	1	16	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	33
45.191	10	.	5	.	1	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20
45.194	4	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	7
45.198	16	5	7	.	2	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	32
45.202	15	4	2	.	2	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	24
45.206	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
45.283	8	.	2	.	2	.	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	17
45.287	79	3	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	84
45.289	114	10	2	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	127
45.293	55	2	4	.	.	.	.	1	.	4	.	.	.	.	.	.	1	.	.	.	.	.	.	67
45.297	103	3	7	.	1	.	.	.	15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	129
45.301	24	1	6	.	1	1	.	.	.	3	.	3	.	.	.	.	.	.	.	.	.	.	.	41
45.305	1035	5	2	.	1	.	.	.	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1046
45.309	148	1	.	.	1	1	.	.	3	4	.	.	.	.	.	.	.	.	.	.	.	.	.	158
45.313	34	.	2	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	38
45.316	31	3	1	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	38
45.319	45	1	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	48
45.321	9	3	2	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	15
45.323	2	2	1	.	.	.	.	.	2	1	.	.	.	.	.	1	.	.	.	.	.	.	.	9
45.325	17	11	42	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	72
45.329	2	3	3	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	8
45.331	2	3	13	.	.	.	.	.	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.	20
45.333	27	1	5	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	13	47
45.335	27	2	8	.	.	3	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	8	51
45.337	12	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	14
45.339	5	.	2	.	.	3	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	5	18
45.341	69	.	3	.	.	1	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	1	74
45.343	32	.	2	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	36
45.344	34	.	1	.	.	3	.	.	.	2	.	.	.	.	.	2	.	.	.	.	.	.	2	45
45.346	19	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.	21
45.348	120	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	1	123
45.350	296	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	298
45.352	65	.	3	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	69
45.356	147	.	11	.	.	6	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	165
45.358	102	.	1	.	.	5	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	109
45.360	32	.	7	.	.	5	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	45
45.362	28	.	6	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	37
45.365	35	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	56
45.367	15	.	7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	17
45.369	103	.	3	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	108
45.371	232	.	13	.	.	9	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	253
45.373	146	.	14	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	164

APPENDIX TABLE 3.—Counts of selected categories of fish larvae, tabulated by station, EASTROPAC II.—*Continued.*

STATION NUMBER	*Vinciguerria* spp.	*Cyclothone* spp.	*Bathylagus nigrigenys*	*Leuroglossus stilbius urotranus*	*Nansenia* sp.	*Diplophos taenia*	*Ichthyococcus irregularis*	*Maurolicus muelleri*	Astronesthidae	*Bathophilus filifer*	*Stomias* sp.	Ewermannellidae	*Macropinnaralepis macrurus*	Scopelosauridae	Scomberesocidae	*Gempylus serpens*	*Nealotus tripes*	*Diplospinus multistriatus*	*Trichiurus lepturus*	*Tetragonurus* spp.	Trachichthyidae	Balistidae	Ostraciontidae	Total: selected categories
45.375	39	.	3	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	43
45.377	75	.	8	.	.	11	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	95
45.379	797	1	2	.	.	7	.	.	.	.	.	.	.	.	.	4	.	.	.	.	.	1	.	812
45.381	244	.	4	.	.	4	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	253
45.383	18	.	4	.	.	2	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	26
45.385	60	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	61
45.387	428	1	.	.	.	.	.	.	.	3	1	.	.	.	.	.	.	.	.	.	.	.	.	433
CRUISE	46																							
46.002	18	.	2	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	21
46.004	116	.	4	.	.	4	.	.	.	3	.	.	.	.	.	1	.	.	.	.	.	.	.	130
46.006	18	.	1	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	21
46.007	28	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	28
46.009	22	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	24
46.011	69	.	1	.	.	3	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	75
46.013	47	.	.	.	.	4	.	.	.	5	.	.	.	.	.	.	.	.	.	.	.	.	1	57
46.015	16	.	1	.	.	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	19
46.017	4	.	5	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	11
46.019	147	.	1	.	.	1	.	.	.	2	.	.	.	.	.	2	1	.	.	.	.	.	.	154
46.020	78	.	10	.	.	2	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	92
46.022	14	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	16
46.024	21	5	5	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	33
46.026	131	9	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	145
46.028	154	2	12	.	.	1	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	171
46.030	7	.	8	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	16
46.032	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
46.034	35	5	5	.	.	.	.	.	1	.	.	.	.	.	.	3	.	.	.	.	.	.	.	49
46.036	91	36	7	.	.	.	.	.	1	.	.	.	.	.	.	.	1	.	.	.	.	.	.	136
46.038	4	3	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10
46.040	19	1	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	.	.	.	.	.	.	23
46.042	129	4	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	137
46.044	95	.	1	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	98
46.046	56	1	1	.	1	.	.	.	.	.	1	.	.	.	.	1	.	.	.	.	.	.	.	61
46.048	53	1	10	.	.	.	.	.	.	.	.	.	1	.	.	2	.	.	.	.	.	.	.	67
46.050	175	6	12	.	.	.	1	1	.	.	.	1	3	.	.	2	.	.	.	.	.	.	.	201
46.052	206	9	7	.	.	.	.	2	.	.	.	8	2	.	.	.	1	.	.	.	.	.	.	235
46.054	177	2	20	.	.	.	.	.	.	.	.	.	1	.	.	.	2	.	.	.	.	.	.	202
46.055	66	4	5	.	.	.	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	78
46.057	610	36	10	.	.	.	.	.	.	1	.	2	1	2	.	1	.	.	.	.	.	.	.	665
46.059	480	23	2	.	.	.	.	.	.	1	2	.	.	14	.	.	3	.	.	1	.	.	.	526
46.061	85	7	3	.	3	.	.	6	1	.	.	.	.	10	.	.	.	.	.	1	.	.	.	116
46.063	16	.	2	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	21
46.065	76	18	4	.	.	.	.	3	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	103
46.067	104	13	5	.	2	.	2	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	129
46.069	52	1	22	.	5	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	82
46.071	26	.	14	.	3	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	45
46.075	20	1	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	26
46.077	17	2	1	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	2	.	.	.	23
46.079	23	.	23	.	1	.	1	6	1	.	.	.	.	3	.	.	.	.	.	.	.	.	.	65
46.082	10	.	17	.	.	.	.	36	4	.	.	.	.	7	.	.	.	.	.	.	.	.	.	74

APPENDIX TABLE 3.—Counts of selected categories of fish larvae, tabulated by station, EASTROPAC II.—*Continued.*

STATION NUMBER	Vinciguerria spp.	Cyclothone spp.	Bathylagus nigrigenys	Leuroglossus stilbius urotranus	Nansenia sp.	Diplophos taenia	Ichthyococcus irregularis	Maurolicus muelleri	Astronesthidae	Bathophilus filifer	Stomias sp.	Evermannellidae	Macroparalepis macrurus	Scopelosauridae	Scomberesocidae	Gempylus serpens	Nealotus tripes	Diplospinus multistriatus	Trichiurus lepturus	Tetragonurus spp.	Trachichthyidae	Balistidae	Ostraciontidae	Total: selected categories
46.084	17	1	21	.	6	.	2	19	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	67
46.086	66	2	33	.	2	.	1	169	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	274
46.088	27	7	8	.	1	.	2	24	.	1	.	.	.	1	.	.	1	.	.	.	.	.	.	72
46.090	17	4	4	.	.	.	.	3	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	29
46.092	13	5	3	.	.	.	.	11	1	3	.	.	.	.	.	.	.	.	.	.	.	.	.	36
46.094	145	4	3	.	.	.	2	.	1	.	.	2	1	.	.	.	.	.	.	.	.	.	.	163
46.096	226	21	13	.	.	.	2	.	.	.	.	3	3	.	.	.	2	.	.	.	.	.	.	270
46.098	40	2	2	.	.	.	.	.	.	8	.	.	.	.	.	.	.	.	.	.	.	.	.	52
46.100	6	.	2	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10
46.102	48	6	3	.	1	.	2	.	.	4	.	.	3	.	.	.	.	.	.	.	.	.	.	67
46.104	46	2	.	.	.	.	.	.	.	1	.	.	1	.	.	1	.	.	.	.	.	.	.	51
46.106	34	7	9	.	.	.	.	.	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.	52
46.108	36	2	27	.	.	.	.	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	69
46.110	10	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	15
46.112	75	.	16	.	.	.	.	.	.	1	.	.	.	.	.	.	1	.	.	.	.	.	.	93
46.114	6	.	3	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	10
46.116	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5
46.118	85	.	3	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	89
46.120	100	.	1	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	103
46.122	29	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	33
46.124	22	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	24
46.126	98	.	10	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	109
46.128	130	.	8	.	1	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	142
46.130	53	.	11	.	.	.	.	.	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.	66
46.132	26	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	35
46.134	12	.	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20
46.135	12	.	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20
46.137	28	.	24	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	54
46.139	50	1	11	.	.	.	1	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	64
46.141	20	.	18	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	1	.	.	.	41
46.143	14	1	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	27
46.145	118	1	38	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	157
46.147	41	.	41	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	83
46.149	11	3	22	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	37
46.151	4	4	13	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22
46.153	163	1	4	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	169
46.155	132	5	6	.	.	.	.	.	.	2	.	.	.	.	.	2	6	.	.	.	.	.	.	156
46.157	24	2	6	.	.	.	1	.	.	.	.	.	2	.	.	4	1	.	.	.	.	.	.	40
46.159	10	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	15
46.161	35	12	8	.	1	.	.	.	2	.	.	2	.	.	.	.	4	.	.	.	.	.	.	64
46.163	80	4	10	.	.	.	.	4	.	3	.	.	.	.	.	1	1	.	.	.	.	.	.	103
46.165	22	7	10	.	.	.	.	7	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	56
46.167	25	4	37	.	.	.	1	10	.	.	.	.	.	.	.	.	5	.	.	.	.	.	.	82
46.169	149	1	52	.	.	.	1	85	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	290
46.171	13	.	44	.	.	.	1	41	.	1	.	.	.	3	.	.	.	.	.	.	.	.	.	103
46.173	1	.	9	1	.	.	.	14	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25
46.175	1	.	21	.	.	.	.	74	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	96
46.177	20	5	45	.	.	.	3	5	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	80
46.179	82	1	135	.	.	.	2	24	1	.	.	.	.	1	.	.	.	.	.	1	.	.	.	247
46.181	53	4	132	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	191
46.183	17	3	47	.	4	.	1	.	3	.	2	.	.	1	.	.	.	.	.	.	.	.	.	78
46.185	90	5	45	.	1	.	2	.	3	.	2	.	.	.	.	.	.	.	.	.	.	.	.	148

APPENDIX TABLE 3.—Counts of selected categories of fish larvae, tabulated by station, EASTROPAC II.—*Continued.*

STATION NUMBER	Vinciguerria spp.	Cyclothone spp.	Bathylagus nigrigenys	Leuroglossus stilbius urotranus	Nansenia sp.	Diplophos taenia	Ichthyococcus irregularis	Maurolicus muelleri	Astronesthidae	Bathophilus filifer	Stomias sp.	Evermannellidae	Macroparalepis macrurus	Scopelosauridae	Scomberesocidae	Gempylus serpens	Nealotus tripes	Diplospinus multistriatus	Trichiurus lepturus	Tetragonurus spp.	Trachichthyidae	Balistidae	Ostraciontidae	Total: selected categories
46.187	39	3	17	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	60
46.189	5	.	8	.	.	.	.	.	.	.	1	.	.	.	.	.	1	.	.	.	.	.	.	15
CRUISE	47																							
47.001	61	2	4	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	11	.	.	.	.	79
47.005	203	3	6	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	5	.	.	.	.	219
47.008	49	.	7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6	.	.	.	.	62
47.011	26	.	3	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	30
47.019	221	13	5	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	18	.	.	.	.	258
47.022	27	2	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	13	.	.	.	.	45
47.025	58	.	4	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	63
47.028	117	1	14	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	133
47.032	137	4	15	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	1	.	159
47.034	36	.	7	.	.	.	.	.	.	.	.	.	.	10	.	.	4	.	.	.	.	.	.	57
47.035	70	3	20	.	.	.	.	.	.	1	.	.	.	8	.	3	1	.	.	.	.	.	.	106
47.040	76	.	8	.	.	.	.	7	.	.	.	.	1	2	.	.	7	.	.	.	.	.	.	101
47.049	92	1	26	.	.	.	.	14	2	2	.	.	.	5	.	.	3	.	.	.	.	.	.	145
47.053	94	1	27	.	.	.	1	5	.	6	.	.	1	59	.	.	8	.	3	.	.	.	.	205
47.057	106	3	50	.	.	.	3	3	.	.	.	.	.	55	.	.	47	.	4	.	.	.	.	271
47.061	18	.	11	.	.	.	.	1	.	.	.	.	.	6	.	.	16	.	3	.	.	.	.	55
47.065	91	.	26	4	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	122
47.069	49	.	21	122	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	14	.	.	207
47.070	17	.	12	176	.	.	.	1	.	.	4	.	.	.	1	.	1	.	.	.	21	.	.	233
47.074	14	.	7	294	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	20	.	.	337
47.078	4	.	3	61	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	2	.	.	71
47.082	6	.	1	79	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	86
47.086	11	.	3	527	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	541
47.090	5	.	6	77	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	89
47.094	2	.	1	7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	11
47.097	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1
47.099	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	3
47.101	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	3
47.103	.	.	2	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	3
47.105	5	.	5	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	11
47.107	7	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11
47.109	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
47.113	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
47.124	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
47.128	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
47.132	8	1	3	.	.	.	.	.	.	.	.	.	.	1	1	.	.	1	.	.	.	.	.	15
47.134	8	.	.	.	.	.	.	.	.	.	.	.	.	.	19	.	.	1	.	.	.	.	.	28
47.137	9	1	3	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	14
47.139	11	.	5	.	.	.	.	.	.	.	.	.	.	.	4	.	.	1	.	.	.	.	.	21
47.141	16	.	13	.	.	.	.	.	.	.	.	.	.	.	4	.	.	1	.	.	.	.	.	34
47.143	2	.	16	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.	.	.	22
47.145	14	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	19
47.147	76	1	16	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.	.	.	97
47.149	27	.	15	.	.	.	.	.	2	1	.	.	.	.	.	.	.	3	.	.	.	.	.	48
47.151	3	.	4	.	.	.	.	.	.	.	.	.	.	.	1	.	.	5	.	.	.	.	.	13
47.153	9	4	17	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	.	.	.	.	.	35

APPENDIX TABLE 3.—Counts of selected categories of fish larvae tabulated by station, EASTROPAC II.—*Continued.*

STATION NUMBER	Vinciguerria spp.	Cyclothone spp.	Bathylagus nigrigenys	Leuroglossus stilbius urotranus	Nansenia sp.	Diplophos taenia	Ichthyococcus irregularis	Maurolicus muelleri	Astronesthidae	Bathophilus filifer	Stomias sp.	Evermannellidae	Macroparalepis macrurus	Scopelosauridae	Scomberesocidae	Gempylus serpens	Nealotus tripes	Diplospinus multistriatus	Trichiurus lepturus	Tetragonurus spp.	Trachichthyidae	Ballistidae	Ostrachontidae	Total: selected categories
47.155	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
47.157	74	3	27	.	.	.	.	.	.	.	.	.	.	.	.	.	1	7	.	.	.	.	.	112
47.159	11	.	14	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	26
47.162	5	.	6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	12
47.164	37	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	49
47.166	19	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22
47.168	1	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	5
47.171	38	1	9	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	50
47.173	165	1	17	.	.	.	.	.	.	.	6	.	.	.	.	.	.	.	.	.	.	.	.	189
47.175	95	.	15	1	.	.	.	.	.	.	1	.	.	.	2	.	.	.	.	.	.	.	.	114
47.177	100	.	34	123	.	.	.	.	.	.	69	.	.	.	1	.	.	.	.	.	.	.	.	327
47.179	14	.	28	161	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	1	.	.	207
47.181	31	.	15	44	.	.	.	1	.	.	6	.	.	.	.	.	.	.	.	.	.	.	.	97
47.185	30	1	21	119	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	6	.	.	177
47.189	4	.	27	70	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	104
47.193	2	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	4
47.197	7	.	31	92	.	.	1	.	.	.	.	.	.	2	1	.	.	.	.	.	1	.	.	135
47.201	142	4	66	74	.	.	.	.	2	.	.	.	.	2	.	.	.	.	.	.	2	.	.	292
47.205	38	1	125	27	.	.	.	6	.	1	1	.	.	7	.	.	1	.	.	.	.	.	.	207
47.213	415	12	58	.	.	.	2	7	.	1	.	.	.	36	.	1	2	.	.	.	.	.	.	534
47.217	84	1	30	.	.	.	1	3	.	.	.	.	1	13	.	.	2	.	.	.	.	.	.	135
47.221	30	1	30	.	.	.	5	.	.	.	.	.	1	13	.	1	2	.	.	.	.	.	.	83
47.225	146	4	34	.	.	.	.	.	2	.	.	.	.	2	.	3	6	.	.	.	.	.	.	197
47.229	256	16	17	.	.	.	.	.	1	2	.	.	1	.	.	1	4	.	.	.	.	.	.	298
47.233	241	8	14	.	.	.	.	.	1	.	.	.	2	.	.	2	6	.	.	.	.	.	.	274
47.237	16	1	8	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	26
47.240	44	2	3	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	50
47.242	91	3	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	115
47.244	174	5	22	.	.	.	.	.	.	.	5	.	.	.	.	1	2	.	7	.	.	.	.	166
47.246	7	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	11
47.250	19	.	3	.	.	.	.	.	.	3	3	.	.	.	.	1	1	.	7	.	.	.	.	36
47.254	27	.	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.	.	39
47.258	36	1	3	.	.	.	1	.	.	.	.	.	.	.	.	1	.	.	5	.	.	.	.	47
47.268	15	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	16
47.272	6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	8
47.276	208	.	45	.	.	.	.	.	.	.	1	.	.	.	.	.	1	.	9	.	.	.	.	264
47.278	33	5	6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	47
47.280	7	1	14	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	24
47.283	4	2	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10
47.286	12	2	18	.	.	.	1	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	36
47.288	44	.	11	.	.	.	.	.	.	1	.	.	.	.	.	.	2	.	.	.	.	.	.	58
47.290	11	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	16
47.292	29	1	7	.	.	.	.	.	.	.	.	.	.	.	.	7	.	.	.	.	.	.	.	44
47.295	91	9	7	.	.	.	1	.	.	5	.	.	.	.	.	8	4	.	.	.	.	.	.	125
47.297	122	14	17	.	.	.	.	.	1	8	3	.	.	3	.	13	6	.	.	.	.	.	.	187
47.301	53	1	8	.	.	.	.	.	1	5	.	.	1	.	.	6	1	.	.	.	.	.	.	76
47.304	17	4	4	.	.	.	.	.	.	1	.	.	.	.	.	1	1	.	.	.	.	.	.	28
47.306	60	5	15	.	.	.	.	.	1	8	1	.	.	.	.	8	1	.	.	.	.	.	.	100
47.310	142	11	18	.	.	.	.	.	4	22	.	.	2	.	.	10	10	.	.	.	.	.	.	219
47.314	75	4	24	.	.	.	.	4	2	5	.	1	1	12	.	1	4	.	.	.	.	.	.	133
47.318	45	.	23	.	.	.	.	13	.	2	.	.	.	4	.	.	.	.	.	.	.	.	.	87
47.322	22	1	59	2	.	.	2	5	.	2	.	.	.	8	.	.	.	.	.	.	.	.	.	101

APPENDIX TABLE 3.—Counts of selected categories of fish larvae, tabulated by station, EASTROPAC II.—*Continued.*

STATION NUMBER	Vinciguerria spp.	Cyclothone spp.	Bathylagus nigrigenys	Leuroglossus stilbius urotranus	Nansenia sp.	Diplophos taenia	Ichthyococcus irregularis	Maurolicus muelleri	Astronesthidae	Bathophilus filifer	Stomias sp.	Evermannellidae	Macroparalepis macrurus	Scopelosauridae	Scomberesocidae	Gempylus serpens	Nealotus tripes	Diplospinus multistriatus	Trichiurus lepturus	Tetragonurus spp.	Trachichthyidae	Balistidae	Ostraciontidae	Total: selected categories
47.326	33	1	143	9	.	.	6	.	.	.	1	.	.	43	.	.	.	.	.	.	.	.	.	236
47.330	129	5	123	14	.	.	12	11	1	.	10	.	.	16	.	.	.	.	.	.	.	.	.	311
47.334	28	.	45	3	.	.	.	.	.	.	8	.	.	.	.	.	.	.	.	.	.	.	.	89
47.338	19	.	19	5	.	.	.	.	.	.	8	.	.	.	.	.	.	.	.	.	.	.	.	51
47.342	24	.	17	2	.	.	.	.	.	.	1	.	.	3	7	.	.	.	.	.	.	.	.	54
47.345	44	1	26	.	.	.	.	.	.	1	5	.	.	.	.	.	.	.	.	.	.	.	.	77
47.349	61	.	16	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	79
47.351	66	.	60	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	127
47.354	87	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	87
47.357	66	1	14	.	.	.	.	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	85
47.359	56	.	10	.	.	.	.	.	.	2	.	.	1	.	.	.	.	.	.	.	.	.	.	69
47.362	4	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	7
47.364	7	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10
47.367	22	2	11	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	38
47.369	3	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	8
47.371	7	5	2	.	.	.	.	.	.	1	.	.	.	.	.	.	.	2	.	.	.	.	.	17
47.373	237	2	2	.	.	.	.	.	.	.	.	.	2	.	.	.	.	16	.	.	.	.	.	259
47.376	72	3	9	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	85
47.379	55	.	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	66
47.382	103	1	4	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	111
47.415	7	2	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	11
47.430	108	1	.	.	.	.	.	.	.	.	.	.	.	.	4	.	.	1	.	.	.	.	.	114
47.432	69	32	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	103
47.436	2	.	2	.	.	.	.	.	.	1	.	.	.	.	22	.	1	1	.	.	.	.	.	29
47.438	34	1	1	.	.	.	.	.	.	2	.	.	.	.	15	.	8	3	.	.	.	.	.	64
47.440	107	2	.	.	.	.	.	.	.	10	.	.	.	.	7	.	3	.	.	.	.	.	.	129
47.443	17	.	1	.	.	.	.	.	.	2	.	.	.	.	6	.	.	.	.	.	.	.	.	26
47.446	4	.	2	.	.	.	.	.	.	1	.	.	.	.	7	.	.	.	.	.	.	.	.	14
47.450	76	9	20	.	.	.	.	.	.	5	.	.	.	.	37	.	2	.	.	.	.	.	.	149
47.454	21	3	41	.	1	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	68
47.458	5	.	42	.	.	.	.	.	1	.	2	.	.	.	1	.	.	.	.	1	.	.	.	52
47.462	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
47.466	6	.	7	.	1	.	.	2	.	.	.	.	.	26	.	.	.	.	.	.	.	.	.	42
47.470	3	.	6	.	.	.	.	107	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	119
47.478	26	1	6	.	.	.	.	9	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	45
47.486	30	2	11	.	.	.	.	5	.	.	.	.	.	.	.	2	3	.	.	.	.	.	.	53
47.490	14	.	13	.	.	.	3	7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	37
47.494	10	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	12
47.498	65	6	1	.	1	.	2	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	78
47.501	148	17	13	.	.	.	.	.	.	1	.	.	.	.	.	2	3	.	.	.	.	.	.	184
47.504	49	9	20	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	79
47.507	75	2	6	.	.	.	.	.	.	1	.	.	.	.	.	.	1	.	.	.	.	.	.	85
47.509	64	.	26	.	2	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	93
47.511	2	.	11	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	13
47.513	3	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
47.515	9	2	7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	18
47.517	36	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	37
47.520	80	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	83
47.523	30	.	7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	37
47.525	10	.	6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	16
47.527	132	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	135

APPENDIX TABLE 4.—Summary of occurrences and numbers of larvae of 23 categories, limited in distribution to a broad coastal band or around offshore islands or banks.

STATION NUMBER	Engraulis ringens	Gobiidae	Albula vulpes	Etrumeus acuminatus	Opisthonema sp.	Sardinops sagax	Engraulidae (other)	Synodontidae	Bothus leopardinus	Citharichthys spp.	Cyclopsetta sp.	Syacium ovale	Symphurus spp.	Carangidae	Eucinostomus sp.	Labridae	Mugilidae	Polynemidae	Pomacentridae	Sciaenidae	Scorpaenidae	Serranidae	Carapidae	Total: 23 categories
45.339	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1
45.343	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
45.350	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1
45.358	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1
45.360	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	1	.	.	.	.	1	.	.	4
45.362	.	8	.	.	.	.	1	.	.	.	.	2	.	1	.	1	.	2	.	.	.	1	.	16
45.365	.	31	.	.	.	.	11	1	1	.	.	2	4	11	.	.	.	19	.	.	10	.	.	90
45.367	.	5	.	.	.	.	2	.	1	.	.	.	.	2	.	.	.	.	.	.	.	3	.	13
45.369	.	20	.	.	.	.	1	.	.	.	.	4	1	10	.	2	.	.	6	.	.	9	.	53
45.371	.	1	.	.	.	.	.	.	.	.	.	4	.	.	.	2	.	.	.	.	.	.	.	7
45.373	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	5	.	.	.	.	1	.	.	8
45.375	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	2
45.377	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6	.	.	.	.	5	.	.	11
45.379	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	1
45.381	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	2
CRUISE 46																								
46.002	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	1	.	.	1
46.004	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	1	.	.	.	.	.	.	.	2
46.006	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1
46.007	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
46.009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	2
46.011	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	2
46.042	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1
46.052	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	3
46.059	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
46.082	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
46.108	.	.	.	.	.	.	.	.	1	.	.	2	.	.	.	.	.	.	.	.	.	.	.	3
46.110	.	.	.	.	.	.	.	.	4	.	.	8	.	.	.	.	.	.	.	.	.	.	.	12
46.112	.	2	.	.	.	.	.	.	22	.	.	18	3	.	.	.	.	.	.	.	.	.	.	45
46.114	.	.	.	.	.	.	.	.	2	.	.	1	1	.	.	1	.	.	.	.	.	.	.	5
46.116	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1
46.118	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
46.120	.	1	.	.	.	.	.	.	1	.	.	3	1	.	.	2	.	.	.	.	.	.	.	8
46.122	.	.	.	.	.	.	.	.	1	.	.	.	2	.	.	.	.	.	.	.	2	.	.	5
46.124	.	.	.	.	.	.	.	.	.	.	1	1	2	.	.	.	.	.	.	.	.	.	.	4
46.126	.	4	.	.	.	.	.	.	5	.	.	3	.	1	.	1	.	1	.	.	.	.	.	15
46.128	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	3
46.130	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	2
46.132	.	.	.	.	.	.	.	.	.	.	.	1	1	1	.	.	.	.	.	.	1	.	.	4
46.134	.	.	.	.	1	.	2	.	1	.	.	10	6	7	.	.	.	.	.	45	18	1	.	91
46.135	.	2	.	.	.	.	1	1	1	.	11	1	6	45	.	.	.	4	.	48	23	.	.	143
46.137	.	12	.	.	.	.	.	5	.	.	13	132	76	2	.	.	.	.	.	.	32	4	.	276
46.139	.	2	.	.	.	.	.	.	.	.	.	2	3	1	.	.	.	.	.	.	1	.	.	9
46.141	.	.	.	.	.	.	.	.	.	.	.	2	2	.	.	.	.	.	.	.	3	.	.	7
46.147	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.	2	.	.	4
46.149	.	.	.	.	.	.	.	.	2	.	.	.	2	.	.	.	.	.	.	.	.	.	.	4
46.151	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1
46.153	.	1	.	.	.	.	.	.	1	.	.	14	.	.	.	.	.	.	.	.	.	.	.	16
46.155	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
46.157	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
46.163	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
46.165	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	1	.	.	3

APPENDIX TABLE 4.—Summary of occurrences and numbers of larvae of 23 categories, limited in distribution to a broad coastal band or around offshore islands or banks.—*Continued.*

STATION NUMBER	Engraulis ringens	Gobiidae	Albula vulpes	Etrumeus acuminatus	Opisthonema sp.	Sardinops sagax	Engraulidae (other)	Synodontidae	Bothus leopardinus	Citharichthys spp.	Cyclopsetta sp.	Syacium ovale	Symphurus spp.	Carangidae	Eucinostomus sp.	Labridae	Mugilidae	Polynemidae	Pomacentridae	Sciaenidae	Scorpaenidae	Serranidae	Carapidae	Total: 23 categories
46.171	.	2	.	3	.	64	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	69
46.173	.	2	.	.	.	2	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	5
46.175	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
46.177	.	.	.	.	.	20	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	21
46.179	.	3	.	1	.	81	.	.	.	21	.	.	.	.	.	1	.	.	.	.	.	.	.	107
46.181	.	.	.	3	.	8	.	.	.	8	.	.	1	.	.	.	.	.	.	.	.	.	.	20
46.185	.	.	.	.	.	.	.	.	.	4	.	.	1	.	.	.	.	.	.	.	.	.	.	5
46.187	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	5	.	6
CRUISE 47																								
47.001	.	9	.	.	.	.	.	4	.	.	.	3	3	4	.	.	.	.	.	.	1	.	.	24
47.005	.	46	.	.	.	.	.	5	.	.	.	11	2	2	.	.	.	.	.	.	3	.	.	69
47.008	.	35	.	.	.	.	.	2	3	5	.	2	3	1	1	.	.	.	.	.	3	.	1	56
47.011	.	11	.	.	.	.	.	.	.	.	1	.	1	11	.	.	.	.	.	.	1	.	.	25
47.019	.	36	2	.	.	.	5	7	1	.	3	5	9	5	4	4	7	2	2	.	4	7	.	103
47.022	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	2	.	3
47.025	.	5	.	.	.	.	.	.	.	1	.	.	.	.	.	1	.	.	1	.	.	.	.	8
47.028	.	24	.	.	.	.	.	.	.	.	.	3	12	.	.	.	.	.	.	.	1	.	.	40
47.032	.	6	.	.	.	.	.	.	.	.	.	4	2	.	.	.	.	.	.	.	5	.	.	17
47.034	.	2	.	.	.	.	.	.	.	.	.	3	9	3	.	.	.	.	.	.	10	.	.	27
47.035	.	.	.	.	.	.	.	.	.	.	.	.	1	5	.	.	.	.	.	.	6	.	.	12
47.040	.	19	.	.	.	.	28	3	.	2	.	3	1	6	7	6	3	.	1	1	10	17	.	107
47.049	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
47.053	.	.	.	.	.	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2
47.057	.	5	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1	.	.	7
47.061	.	2	.	.	.	.	.	1	.	.	.	.	1	.	.	.	.	.	.	.	2	.	.	6
47.065	.	3	.	.	.	.	.	.	.	1	1	.	4	4	.	1	2	.	1	.	1	.	1	19
47.069	1	6	.	.	.	.	.	1	.	.	1	3	2	.	.	1	.	.	.	.	.	.	.	15
47.070	.	2	.	.	.	.	.	.	.	2	.	1	1	.	.	.	2	.	.	.	.	.	.	8
47.074	.	13	.	.	.	.	.	.	.	9	.	1	1	.	.	.	.	.	.	1	1	3	.	29
47.078	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1	.	.	2
47.082	26	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	26
47.086	127	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	127
47.090	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
47.097	250	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	252
47.099	48	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11	.	.	.	59
47.101	222	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	222
47.103	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
47.105	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
47.107	4	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	7
47.109	293	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	293
47.113	35	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	35
47.124	99	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	99
47.128	96	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	96
47.132	43	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	43
47.139	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
47.141	12	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	12
47.147	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
47.162	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
47.173	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
47.175	13	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	13
47.177	4	5	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	10

APPENDIX TABLE 4.—Summary of occurrences and number of larvae of 23 categories, limited in distribution to a broad coastal band or around offshore islands or banks.—*Continued.*

STATION NUMBER	Engraulis ringens	Gobiidae	Albula vulpes	Etrumeus acuminatus	Opisthonema sp.	Sardinops sagax	Engraulidae (other)	Synodontidae	Bothus leopardinus	Citharichthys spp.	Cyclopsetta sp.	Syacium ovale	Symphurus spp.	Carangidae	Eucinostomus sp.	Labridae	Mugilidae	Polynemidae	Pomacentridae	Sciaenidae	Scorpaenidae	Serranidae	Carapidae	Total: 23 categories
47.179	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
47.181	1	3	.	.	.	.	.	.	.	1	.	.	.	.	.	1	.	.	.	.	3	1	.	10
47.185	13	1	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.	1	1	1	.	19
47.189	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	2
47.197	9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	11
47.201	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	1	.	.	2
47.229	.	3	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.	2	.	.	7
47.233	.	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	4	.	.	6
47.237	.	1	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	2	.	.	5
47.240	.	5	.	.	.	.	.	.	2	.	.	.	.	.	.	1	.	.	.	.	1	.	.	9
47.242	.	4	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	1	.	.	7
47.244	.	.	.	.	.	.	.	.	1	.	.	2	1	.	.	.	.	.	.	.	.	1	.	5
47.246	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
47.250	.	.	.	.	.	.	.	.	.	.	.	1	2	.	.	.	.	.	.	.	.	.	.	3
47.254	.	3	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	2	.	.	.	1	.	8
47.258	.	5	.	.	.	.	.	4	.	10	.	3	4	16	.	.	2	.	.	1	36	3	.	84
47.268	.	.	.	.	.	.	.	1	.	1	2	.	9	.	.	.	.	.	.	.	5	3	.	21
47.272	.	1	.	.	.	.	.	.	.	.	1	.	4	3	.	.	.	.	.	.	2	2	.	13
47.276	.	8	.	.	.	.	.	.	.	.	.	4	2	.	.	3	.	.	.	.	.	.	.	17
47.278	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	2	.	3
47.283	.	1	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	3
47.286	.	1	.	.	.	.	.	.	1	.	.	1	5	.	.	1	.	.	.	.	.	.	.	9
47.288	.	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1	3
47.290	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
47.292	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1
47.295	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1
47.301	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	1
47.304	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	2
47.306	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	4	.	5
47.310	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	3	.	5
47.314	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	2
47.322	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
47.330	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
47.334	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
47.349	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
47.357	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1
47.436	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1
47.446	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1
47.450	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1
47.466	.	.	.	.	.	2	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	3
47.470	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	1	.	.	2
47.501	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1
47.504	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	2
47.507	.	.	.	.	.	.	.	.	.	.	.	3	1	1	.	.	.	.	.	.	.	.	.	5
47.509	.	.	.	.	.	.	.	.	3	.	.	2	.	.	.	.	.	.	.	.	.	.	.	5
47.511	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	1	.	.	2
47.513	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1
47.515	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
47.517	.	1	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	3
47.520	.	8	.	.	.	.	.	.	.	.	.	13	8	.	.	1	.	.	.	.	13	.	.	43
47.523	.	.	.	.	.	.	.	.	.	.	.	1	2	.	.	1	.	.	.	.	2	1	.	7
47.525	.	.	.	.	.	.	.	.	1	.	.	3	4	.	.	.	.	.	.	.	1	.	.	9
47.527	.	7	7	.	83	.	1	23	36	.	1	180	142	69	3	.	.	.	.	15	1	.	.	568

APPENDIX TABLE 5.—Numbers and kinds of eel leptocephali (Anguilliformes) obtained on the second multivessel EASTROPAC survey (EASTROPAC II), tabulated by family for all positive hauls.

STATION NUMBER	Eel leptocephali	Congridae	Moringuidae	Muraenidae	Nemichthyidae	Ophichthidae	Serrivomeridae	Xenocongridae	Family unknown
45 .018	2	.	.	.	2	.	.	.	.
45 .023	1	.	.	.	1	.	.	.	.
45 .030	1	.	.	.	.	.	1	.	.
45 .058	1	.	.	.	.	.	1	.	.
45 .063	1	.	.	.	.	.	.	.	1
45 .065	2	.	.	.	.	.	2	.	.
45 .067	2	.	.	.	.	.	2	.	.
45 .071	1	.	.	.	.	.	1	.	.
45 .073	1	.	.	.	.	.	.	.	1
45 .140	2	.	.	.	1	.	.	.	1
45 .313	1	.	.	.	.	.	1	.	.
45 .362	1	1	.	.	.	.	.	.	.
45 .365	12	4	1	.	.	7	.	.	.
45 .367	3	1	.	.	.	.	.	.	2
45 .371	1	.	.	.	.	1	.	.	.
45 .379	1	.	.	.	1	.	.	.	.
46 .032	1	1	.	.	.	.	.	.	.
46 .034	1	.	.	.	.	.	.	.	1
46 .046	2	.	.	.	.	.	.	.	2
46 .065	1	1	.	.	.	.	.	.	.
46 .077	1	1	.	.	.	.	.	.	.
46 .086	2	.	.	.	1	.	.	1	.
46 .098	1	.	.	.	.	.	.	.	1
46 .106	1	.	.	.	1	.	.	.	.
46 .108	1	.	.	.	1	.	.	.	.
46 .110	2	.	.	1	.	1	.	.	.
46 .112	1	.	.	.	1	.	.	.	.
46 .114	1	.	.	1	.	.	.	.	.
46 .120	1	.	.	.	.	1	.	.	.
46 .122	1	1	.	.	.	.	.	.	.
46 .124	2	.	.	.	.	2	.	.	.
46 .128	1	1	.	.	.	.	.	.	.
46 .130	2	2	.	.	.	.	.	.	.
46 .134	2	.	.	.	.	2	.	.	.
46 .135	3	.	.	.	.	3	.	.	.
46 .137	1	1	.	.	.	.	.	.	.
46 .139	4	2	.	.	.	2	.	.	.
46 .143	1	.	.	.	.	1	.	.	.
46 .145	2	1	.	1	.	.	.	.	.
46 .153	1	.	.	.	1	.	.	.	.
46 .155	1	.	.	.	1	.	.	.	.
46 .157	1	.	.	.	1	.	.	.	.
46 .161	1	.	.	.	.	.	.	.	1
46 .165	1	.	.	.	1	.	.	.	.
46 .169	1	.	.	.	1	.	.	.	.
46 .177	1	.	.	.	.	.	.	1	.
47 .001	3	1	.	.	.	2	.	.	.
47 .008	1	1	.	.	.	.	.	.	.
47 .011	3	2	.	.	.	1	.	.	.
47 .019	11	4	.	2	.	5	.	.	.
47 .028	2	.	1	.	.	1	.	.	.
47 .032	1	.	1	.	.	.	.	.	.
47 .035	1	1	.	.	.	.	.	.	.
47 .040	6	.	.	.	.	3	.	.	3
47 .049	2	.	.	.	.	2	.	.	.
47 .053	2	.	.	.	.	.	.	1	1
47 .069	1	.	.	.	.	1	.	.	.
47 .070	1	.	.	.	.	1	.	.	.
47 .107	1	.	.	.	.	1	.	.	.
47 .179	1	.	.	.	.	1	.	.	.
47 .197	1	.	.	.	.	1	.	.	.
47 .217	1	1	.	.	.	.	.	.	.
47 .229	1	1	.	.	.	.	.	.	.
47 .233	1	.	.	.	1	.	.	.	.
47 .242	1	.	.	.	1	.	.	.	.
47 .244	1	1	.	.	.	.	.	.	.
47 .254	1	1	.	.	.	.	.	.	.
47 .258	4	2	.	1	.	.	.	.	1
47 .268	1	.	.	.	.	1	.	.	.
47 .276	1	1	.	.	.	.	.	.	.
47 .283	1	.	.	.	.	1	.	.	.
47 .286	1	.	.	.	1	.	.	.	.
47 .297	3	1	.	.	.	.	.	.	2
47 .304	2	.	.	.	1	.	.	1	.
47 .314	3	2	.	.	1	.	.	.	.
47 .438	2	.	.	.	2	.	.	.	.
47 .478	1	.	.	.	.	1	.	.	.
47 .504	1	.	.	.	.	1	.	.	.
47 .509	1	1	.	.	.	1	.	.	1
47 .525	3	3	.	.	.	.	.	.	.
47 .527	7	2	.	.	.	5	.	.	.

APPENDIX TABLE 6.—Numbers and kinds of lophiiform larvae obtained on the second multivessel EASTROPAC survey (EASTROPAC II), tabulated by family for all positive hauls.

STATION NUMBER	Caulophrynidae	Centrophrynidae	Ceratiidae	Gigantactinidae	Himantolophidae	Linophrynidae	Melanocoetidae	Oneirodidae	Unidentified Ceratioidei	Antennariidae	Lophiidae
45 .037	.	.	.	.	.	1	.	.	.	.	.
45 .039	.	.	.	1	.	.	.	.	1	.	.
45 .044	.	.	.	1	.	.	.	.	.	.	.
45 .046	.	.	.	1	.	.	.	.	.	.	.
45 .048	.	.	.	.	.	.	.	1	1	.	.
45 .050	.	.	.	.	1	.	.	.	1	.	.
45 .051	.	.	.	.	.	.	.	1	1	.	.
45 .053	.	.	.	.	.	.	.	1	.	.	.
45 .054	.	.	.	.	.	.	.	1	.	.	.
45 .056	.	.	.	1	.	.	1	1	.	.	.
45 .058	.	.	.	1	1	.	.	1	.	.	.
45 .060	.	.	.	.	.	.	.	1	.	.	.
45 .063	.	.	.	1	.	.	1	.	.	.	.
45 .065	.	.	.	.	.	.	1	.	3	.	.
45 .067	.	.	.	2	2	.	.	.	1	.	.
45 .078	.	.	.	.	.	.	.	1	.	.	.
45 .110	.	.	.	.	.	.	.	1	.	.	.
45 .127	.	.	.	.	.	.	.	1	.	.	.
45 .131	.	.	.	1	.	.	.	.	.	.	.
45 .171	.	.	.	1	.	.	.	.	.	.	.
45 .175	.	.	.	.	.	1	.	.	.	.	.
45 .309	.	.	.	.	1	.	.	.	.	.	.
45 .319	.	.	.	.	.	.	.	1	1	.	.
45 .321	.	.	.	.	.	.	.	.	1	.	.
45 .325	.	1	.	.	.	.	.	.	1	.	.
46 .028	1	.	.	.	.	.	1	.	.	.	.
46 .034	.	.	.	.	.	.	.	1	1	.	.
46 .044	.	.	.	.	.	.	.	.	1	.	.
46 .046	.	.	.	1	1	.	.	2	.	.	.
46 .048	.	.	.	.	.	.	1	.	.	.	.
46 .052	.	.	.	.	.	.	.	1	.	.	.
46 .057	.	.	.	.	.	.	.	1	.	.	.
46 .059	.	.	.	.	.	.	.	.	1	.	.
46 .086	.	.	.	.	.	.	.	1	.	.	.
46 .088	.	.	.	.	.	.	1	.	.	.	.
46 .094	.	.	.	.	.	.	.	.	1	.	.
46 .098	.	.	1	.	.	.	.	.	.	.	.
46 .100	.	.	.	1	.	.	.	.	.	.	.
46 .102	.	.	.	1	.	.	.	2	.	.	.
46 .104	.	.	.	.	.	.	.	.	1	.	.
46 .108	.	.	.	.	.	.	1	.	.	.	.
46 .110	.	.	.	.	.	.	1	.	.	.	.
46 .112	.	.	.	.	.	.	.	2	.	.	.
46 .114	.	.	.	.	.	.	1	.	.	.	.
46 .122	.	.	.	.	.	.	.	.	1	.	.
46 .126	.	.	.	.	.	.	4	.	.	.	.
46 .128	.	.	.	.	.	.	2	.	1	.	.
46 .132	.	.	.	.	.	.	.	.	.	1	.
46 .139	.	.	.	.	.	.	1	.	.	.	.
46 .145	.	.	.	.	.	.	.	.	.	.	1
46 .153	.	.	.	.	.	.	.	1	.	.	.
46 .155	.	.	.	.	.	.	.	1	.	.	.
46 .159	.	.	.	.	.	.	1	3	.	.	.
46 .161	.	.	2	1	.	.	.	1	.	.	.
46 .163	.	.	.	.	.	.	2	1	.	.	.
46 .165	1	.	.	1	.	.	1	.	.	.	.
46 .167	.	.	.	.	.	.	.	1	.	.	.

STATION NUMBER	Caulophrynidae	Centrophrynidae	Ceratiidae	Gigantactinidae	Himantolophidae	Linophrynidae	Melanocoetidae	Oneirodidae	Unidentified Ceratioidei	Antennariidae	Lophiidae
46 .169	.	.	.	.	.	.	1	.	.	.	.
47 .001	.	.	.	.	.	1	.	.	.	.	.
47 .005	.	.	.	.	.	.	.	1	1	.	.
47 .008	.	.	.	.	.	2	.	1	.	.	.
47 .011	.	.	.	.	.	3	.	.	.	.	.
47 .019	.	.	.	.	.	.	2	2	.	.	.
47 .025	.	.	.	.	.	.	.	2	.	.	.
47 .028	.	.	.	.	.	4	.	2	.	.	.
47 .032	.	.	.	.	.	.	2	.	.	.	.
47 .034	.	.	.	.	.	.	.	1	.	.	.
47 .035	.	.	.	.	.	1	.	.	2	.	.
47 .040	.	.	.	.	1	.	.	.	.	.	.
47 .049	.	.	.	.	.	.	.	1	.	.	.
47 .053	.	.	.	.	1	.	.	5	.	.	.
47 .057	.	.	.	1	.	.	.	.	.	.	.
47 .061	.	.	.	.	.	.	.	1	.	.	.
47 .074	.	.	.	.	.	2	.	.	.	.	.
47 .090	.	.	.	.	.	1	.	.	.	.	.
47 .141	.	.	.	.	.	1	.	.	.	.	.
47 .177	.	.	.	.	.	1	.	.	.	.	.
47 .197	.	.	.	.	.	1	.	.	.	.	.
47 .201	.	.	.	.	.	1	.	.	.	.	.
47 .213	.	.	.	.	.	.	.	4	.	.	.
47 .217	.	.	.	.	.	.	.	4	.	.	.
47 .225	.	.	.	.	.	.	.	3	2	.	.
47 .229	.	.	.	.	.	1	1	1	1	.	.
47 .240	.	.	.	.	.	.	.	.	1	.	.
47 .242	.	.	.	.	.	2	1	.	.	.	.
47 .244	.	.	.	.	.	.	4	6	.	.	.
47 .246	.	.	.	.	.	.	1	1	.	.	.
47 .250	.	.	.	.	.	1	.	2	.	.	.
47 .254	.	.	.	.	.	.	.	.	1	.	.
47 .268	.	.	.	.	.	1	.	.	.	.	.
47 .276	.	.	.	.	.	1	.	.	.	.	.
47 .283	.	.	.	.	.	.	1	.	.	.	.
47 .286	.	.	.	.	.	.	2	.	.	.	.
47 .292	.	.	.	.	.	.	.	1	.	.	.
47 .295	.	.	.	.	.	.	.	4	.	.	.
47 .297	.	.	.	.	.	.	.	1	.	.	.
47 .306	.	.	.	.	.	.	.	.	4	.	.
47 .310	.	.	.	.	6	.	2	1	5	2	.
47 .322	.	.	.	3	.	.	.	1	1	.	.
47 .326	.	.	.	.	.	.	4	.	.	.	.
47 .351	.	.	.	.	.	.	2	.	.	.	.
47 .357	.	.	.	.	.	.	.	1	.	.	.
47 .450	.	.	.	1	.	.	.	.	.	.	.
47 .454	.	.	.	.	.	.	.	.	1	.	.
47 .486	.	.	.	.	1	1	.	.	2	.	.
47 .490	.	.	.	4	.	.	.	.	2	1	.
47 .498	.	.	.	.	1	.	.	1	.	.	.
47 .501	.	.	.	.	.	.	.	1	.	.	.
47 .504	.	.	.	.	.	.	.	1	.	.	.
47 .507	.	.	.	.	.	.	.	1	.	.	.
47 .511	.	.	.	.	.	.	.	1	.	.	.
47 .513	.	.	.	.	.	.	.	1	.	.	.
47 .523	.	.	.	.	.	.	.	1	.	.	.
47 .525	.	.	.	.	.	.	.	1	.	.	.

APPENDIX TABLE 7A.—Counts of fish larvae, tabulated by family, for all stations occupied by *Oceanographer* on zig-transect.

STATION NUMBER	Myctophidae	Gonostomatidae	Bathylagidae	Clupeidae	Engraulidae	Sternoptychidae	Chauliodontidae	Idiacanthidae	Other Stomiatoidei	Paralepididae	Scopelosauridae	Melamphaidae	Bregmacerotidae	Exocoetidae	Bramidae	Chiasmodontidae	Coryphaenidae	Nomeidae	Scombridae	Other Identified Larvae	Unidentified Larvae	Disintegrated Larvae	Total Fish Larvae
OP .001	8	.	.	.	7	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	17
OP .002	2	.	.	.	200	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	202
OP .003	4	.	.	.	74	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	79
OP .005	32	9	3	.	.	.	1	.	.	.	.	2	.	.	.	.	.	3	.	.	.	2	52
OP .007	50	19	11	.	.	.	1	.	.	.	.	.	.	.	.	2	.	3	.	.	.	2	88
OP .009	41	9	12	.	.	1	1	.	.	.	.	18	.	.	.	8	.	1	.	.	.	.	91
OP .011	50	19	6	.	.	.	3	.	.	.	.	4	.	.	.	2	.	7	.	5	1	9	106
OP .013	70	22	20	.	.	.	11	.	.	.	.	3	.	.	.	2	.	3	.	1	.	.	132
OP .015	46	15	24	.	.	.	5	.	.	.	.	1	.	.	2	1	.	.	.	.	2	2	98
OP .017	13	1	1	.	.	5	.	.	.	.	.	2	.	.	.	2	.	1	.	2	.	2	29
OP .019	20	10	8	.	.	16	1	.	1	.	.	1	.	.	1	.	.	3	.	.	3	.	64
OP .021	10	7	4	.	.	6	.	.	.	.	.	2	.	.	.	.	.	4	.	.	1	2	36
OP .023	251	53	15	.	.	61	2	.	1	.	.	5	.	.	.	3	.	.	.	.	.	2	393
OP .025	206	31	8	.	.	19	.	.	2	.	.	3	.	.	.	1	.	3	.	1	.	1	275
OP .027	248	110	111	.	.	41	.	3	8	14	.	9	.	.	.	1	.	13	.	1	.	30	589
OP .029	168	146	153	.	.	26	.	1	18	34	.	5	.	.	1	.	.	12	.	2	1	56	623
OP .032	321	154	213	.	1	54	2	3	17	79	2	16	.	.	.	3	.	7	.	1	1	12	886
OP .036	543	2047	487	.	1	36	.	.	18	57	.	12	.	.	.	.	.	10	.	2	.	25	3238
OP .040	113	126	176	.	.	6	.	.	14	9	.	3	.	.	.	1	.	11	.	1	.	8	468
OP .044	100	64	38	.	.	5	.	1	12	7	.	5	.	.	.	8	.	7	.	17	.	1	265
OP .048	230	103	119	.	.	47	.	.	24	54	20	13	.	.	2	1	.	4	.	18	.	97	732
OP .052	101	52	51	.	.	12	.	.	1	6	34	3	.	.	.	3	1	12	.	14	5	20	315
OP .056	62	20	108	.	.	4	.	1	5	40	26	10	.	.	1	.	1	3	.	5	5	30	321
OP .060	43	26	65	.	.	8	.	1	8	8	5	7	.	3	.	2	1	1	.	2	2	3	185
OP .064	387	51	96	.	.	17	.	.	17	26	21	17	.	.	.	2	1	3	.	7	.	10	655
OP .068	119	40	54	.	.	34	.	.	4	16	11	7	.	.	.	6	.	.	.	12	.	3	306
OP .072	109	7	30	.	.	13	.	1	.	9	1	4	.	.	1	4	.	.	.	4	.	4	187
OP .076	86	22	18	.	.	8	.	.	7	18	1	6	.	.	3	1	.	1	.	3	1	5	180
OP .080	127	67	49	.	.	20	.	.	5	13	2	8	.	.	1	2	.	8	.	1	.	4	307
OP .084	105	12	46	.	.	7	.	1	5	19	.	8	.	.	.	1	.	1	.	3	.	14	222
OP .088	70	28	34	.	.	29	.	1	2	38	.	3	.	.	.	3	.	2	.	3	1	7	221
OP .092	17	6	28	.	.	2	.	.	2	7	.	1	.	.	.	1	.	1	.	9	.	1	75
OP .096	64	7	6	.	.	15	.	.	2	19	2	.	.	.	.	.	.	.	.	2	5	2	124
OP .100	92	4	6	.	.	.	.	.	2	5	4	.	.	.	.	.	.	.	.	1	.	.	114
OP .104	60	16	2	7	.	3	.	2	7	3	.	1	.	.	.	.	.	.	.	2	3	3	109
OP .108	95	44	31	.	.	7	.	7	6	28	3	2	.	.	1	.	.	.	.	1	4	6	235
OP .112	320	100	75	.	.	6	.	.	1	11	4	15	.	.	1	1	.	4	.	8	.	6	552
OP .116	383	123	43	.	.	18	.	.	.	23	2	11	.	.	3	.	.	2	.	7	1	5	621
OP .120	110	6	6	.	.	27	.	1	.	2	.	5	.	.	.	.	.	.	.	3	2	3	165
OP .124	296	3	4	.	.	67	2	1	1	.	.	3	.	.	.	.	1	4	.	4	.	.	386
OP .128	1325	181	20	.	.	133	3	2	4	5	.	4	.	1	.	.	.	2	.	5	1	11	1697
OP .132	1454	229	15	.	.	115	3	.	5	5	.	3	.	.	.	.	1	8	.	7	1	10	1856
OP .136	343	14	4	.	.	17	.	1	1	.	.	.	.	5	.	.	.	5	3	3	.	12	408
OP .138	411	9	15	.	.	54	3	.	3	.	.	5	.	.	.	.	.	4	2	1	.	3	510
OP .155	372	37	52	.	.	20	1	.	2	.	.	5	.	.	.	1	1	1	2	3	.	25	522
OP .160	220	152	27	.	.	11	7	.	4	.	.	2	.	5	3	2	1	5	3	33	.	35	510
OP .162	255	155	6	.	.	.	.	.	.	1	.	4	.	2	2	.	.	15	48	31	1	5	525
OP .164	19	10	1	.	.	3	.	.	.	.	.	1	.	.	.	1	.	9	11	2	.	4	61
OP .166	4	2	1	.	.	3	.	.	.	.	.	2	.	.	.	.	.	2	.	3	.	1	18
OP .168	131	18	62730	477	.	.	.	.	.	.	.	2	470	.	.	.	.	.	13	704	11	5	4567

APPENDIX TABLE 7B.—Myctophid larvae, tabulated by genus or species, stations occupied by *Oceanographer* on zig-transect.

STATION NUMBER	Benthosema pterota panamense	Ceratoscopelus townsendi	Diaphus spp.	Diogenichthys laternatus	Gonichthys tenuiculus	Hygophum atratum	Hygophum proximum	Lampadena spp.	Lampanyctus spp.	Lepidophanes sp.	Lobianchia sp.	Loweina rara	Myctophum aurolaternatum	Myctophum nitidulum	Myctophum sp.	Notolychnus valdiviae	Notoscopelus resplendens	Protomyctophum sp.	Symbolophorus evermanni	Triphoturus spp.	Unidentified Myctophids	Disintegrated Myctophids	Total Myctophids
OP .001	.	.	.	.	.	.	.	.	6	.	.	.	.	.	.	.	.	.	.	1	.	1	8
OP .002	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	2
OP .003	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	2	4
OP .005	.	.	.	2	.	.	.	.	21	.	.	.	.	.	.	.	.	.	1	7	.	1	32
OP .007	.	.	1	8	.	.	.	.	12	.	.	.	.	.	.	.	1	.	16	12	.	.	50
OP .009	.	.	1	8	.	.	.	.	15	.	.	.	.	.	.	.	.	.	4	3	4	6	41
OP .011	.	.	.	10	.	.	.	.	11	.	.	.	.	.	.	.	.	.	7	13	2	7	50
OP .013	.	2	3	15	1	2	.	.	18	.	.	.	.	.	.	.	5	.	8	13	5	1	70
OP .015	.	.	.	5	.	.	.	.	5	.	.	.	.	.	.	.	2	.	19	5	5	2	46
OP .017	.	.	.	3	.	.	.	.	4	.	.	.	.	.	.	.	.	.	.	1	.	5	13
OP .019	.	.	.	5	.	1	.	.	3	.	.	.	.	.	.	.	.	.	7	3	1	.	20
OP .021	.	.	.	1	.	.	.	.	8	.	.	.	.	.	.	.	.	.	.	1	.	.	10
OP .023	.	.	.	188	1	.	.	.	47	.	.	.	.	.	.	.	.	.	1	10	4	.	251
OP .025	.	.	.	180	.	.	.	.	21	.	.	.	.	2	.	.	.	.	.	5	.	.	206
OP .027	.	.	.	213	1	5	.	.	16	.	.	.	.	.	.	.	.	.	2	.	.	8	248
OP .029	.	.	.	113	1	4	.	.	12	.	.	.	.	10	.	.	.	.	2	1	4	20	168
OP .032	.	.	2	229	4	.	.	.	12	.	.	.	3	25	.	.	.	.	5	27	.	13	321
OP .036	.	.	.	487	1	.	.	.	19	.	.	.	.	7	.	.	.	1	.	24	.	5	543
OP .040	.	.	.	65	.	.	.	.	25	.	.	.	.	17	.	.	.	.	.	4	.	2	113
OP .044	.	.	1	43	3	.	.	.	4	.	.	.	4	42	.	.	3	.	.	.	.	.	100
OP .048	.	.	1	51	5	.	.	.	91	.	.	.	5	47	.	.	3	.	.	9	2	16	230
OP .052	.	.	2	51	.	1	.	.	27	.	.	.	.	11	.	.	.	.	.	2	1	8	101
OP .056	.	.	1	18	1	.	.	.	5	.	.	.	.	15	.	1	.	.	.	2	5	14	62
OP .060	.	.	3	11	.	.	.	.	7	.	.	.	.	18	.	.	.	.	.	2	.	2	43
OP .064	.	.	5	253	3	.	.	.	65	.	.	.	1	38	.	.	6	.	.	11	2	5	387
OP .068	.	.	4	24	5	.	.	.	24	.	.	.	5	27	1	.	14	1	1	3	.	8	119
OP .072	.	.	.	16	5	.	.	.	23	.	.	.	1	47	.	.	3	.	.	1	.	13	109
OP .076	.	.	5	24	3	.	.	.	3	.	.	.	.	31	.	.	7	.	.	5	.	8	86
OP .080	.	.	5	46	1	.	.	.	32	.	.	.	1	30	.	.	7	.	.	5	.	.	127
OP .084	.	.	.	55	3	.	.	.	15	.	.	.	1	15	.	1	1	1	.	1	2	12	105
OP .088	.	.	5	26	1	.	.	.	20	.	.	.	1	5	.	.	4	.	4	2	.	2	70
OP .092	.	.	.	6	.	.	.	.	6	.	.	.	.	2	.	.	2	1	.	.	1	.	17
OP .096	.	.	3	41	2	.	.	.	5	.	.	.	.	3	.	.	2	1	.	7	.	.	64
OP .100	.	.	2	77	.	.	.	.	7	.	.	.	.	.	.	.	1	.	1	5	.	.	92
OP .104	.	.	1	20	.	.	.	.	15	.	.	.	.	14	.	.	1	1	.	7	.	1	60
OP .108	.	.	4	32	4	1	.	.	11	.	1	.	1	26	.	.	2	1	.	4	.	5	95
OP .112	.	.	4	256	.	.	1	.	39	.	.	.	3	1	.	.	2	2	3	4	.	5	320
OP .116	.	.	.	347	.	.	.	1	16	.	.	.	6	5	.	.	3	2	1	.	3	.	383
OP .120	.	.	.	97	1	.	.	.	1	.	.	.	2	3	.	.	2	1	1	2	.	1	110
OP .124	.	.	.	265	.	.	.	.	14	.	.	.	3	2	.	.	6	1	1	.	.	.	296
OP .128	.	.	11	188	9	.	.	.	88	.	.	.	9	1	.	.	5	2	1	9	2	11	1325
OP .132	.	.	11	300	2	.	.	.	122	.	.	.	15	1	.	.	2	1	4	3	.	3	1454
OP .136	.	.	.	338	1	.	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	343
OP .138	.	.	.	403	.	.	.	.	7	.	.	.	1	.	.	.	.	.	.	.	.	.	411
OP .155	.	.	.	346	.	.	.	.	18	.	.	.	1	.	.	.	.	.	.	.	.	7	372
OP .160	.	.	2	135	3	.	.	.	65	.	.	.	2	.	.	.	.	.	.	.	.	15	220
OP .162	.	.	.	206	2	.	.	.	45	.	.	.	.	.	.	.	.	.	.	.	.	.	255
OP .164	.	.	.	19	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	19
OP .166	.	.	.	2	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1	4
OP .168	43	.	.	86	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	131

APPENDIX TABLE 7C.—Counts of selected categories of fish larvae, tabulated by station, for *Oceanographer* on zig-transect.

STATION NUMBER	*Bathylagus nigrigenys*	*Leuroglossus stilbius urotranus*	*Cyclothone* spp.	*Ichthyococcus irregularis*	*Maurolicus muelleri*	*Vinciguerria lucetia*	*Bathophilus* sp.	*Stomias* sp.	Scopelarchidae	Trachypteridae	*Diplospinus multistriatus*	*Lepidopus* sp.	*Nealotus tripes*	Carangidae	Gobiidae	Labridae	Sciaenidae	Scorpaenidae	Serranidae	*Bothus leopardinus*	*Citharichthys* spp.	*Syacium ovale*	*Symphurus* spp.	Total: selected categories
OP .001	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	1
OP .002	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
OP .003	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
OP .005	3	.	1	.	.	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	12
OP .007	11	.	1	.	.	18	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	30
OP .009	12	.	1	.	.	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	21
OP .011	5	.	2	.	.	17	.	.	4	.	1	.	.	.	.	.	.	.	.	.	.	.	.	30
OP .013	20	.	3	.	.	19	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	43
OP .015	24	.	6	.	.	9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	39
OP .017	1	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	3
OP .019	8	.	1	.	.	9	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	19
OP .021	4	.	.	.	.	7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11
OP .023	15	.	2	.	.	51	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	69
OP .025	8	.	1	.	.	30	2	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	42
OP .027	44	67	.	.	.	110	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	225
OP .029	52	101	2	.	.	144	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	302
OP .032	69	144	1	.	.	152	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	368
OP .036	36	451	.	.	12046	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2535
OP .040	11	165	.	.	.	125	.	4	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	306
OP .044	24	14	.	.	.	60	.	2	1	.	.	1	1	.	2	1	1	4	.	1	.	.	3	115
OP .048	93	26	1	3	54	41	.	3	.	.	.	.	7	.	3	.	1	1	.	.	1	.	2	236
OP .052	50	1	1	2	5	43	.	.	.	1	.	.	6	.	1	.	.	1	1	.	.	.	.	112
OP .056	102	6	.	1	6	13	1	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	130
OP .060	65	.	.	.	17	9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	91
OP .064	94	2	2	2	6	40	2	4	.	2	.	.	1	.	.	.	.	.	.	.	.	.	.	155
OP .068	44	10	1	.	.	38	.	1	.	.	.	.	4	.	.	.	.	1	.	1	.	.	.	100
OP .072	25	5	.	.	2	3	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	.	37
OP .076	18	.	2	1	2	17	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	41
OP .080	49	.	1	.	.	66	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	118
OP .084	45	1	3	.	4	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	61
OP .088	34	.	6	.	.	22	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	62
OP .092	28	.	3	.	2	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	6	.	.	41
OP .096	6	.	.	2	4	1	.	1	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	16
OP .100	6	.	.	.	1	3	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	12
OP .104	2	.	.	.	7	9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	18
OP .108	31	.	1	2	19	22	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	76
OP .112	75	.	10	.	35	55	.	.	.	3	.	.	1	.	.	.	.	.	.	.	.	.	.	179
OP .116	43	.	9	2	12	100	.	.	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	169
OP .120	8	.	.	.	.	8	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	14
OP .124	4	.	.	.	.	3	.	.	1	.	.	.	1	.	.	1	.	.	.	.	.	.	.	10
OP .128	20	.	14	1	.	166	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	1	.	204
OP .132	15	.	12	3	.	214	.	4	1	.	.	.	.	.	.	.	.	.	.	1	.	2	.	252
OP .136	4	.	.	.	.	14	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	20
OP .138	15	.	.	.	.	9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	24
OP .155	52	.	.	.	.	37	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	1	92
OP .160	27	.	.	.	.	152	.	.	1	.	.	.	.	.	16	.	.	.	.	4	.	4	3	207
OP .162	8	.	3	.	.	152	.	.	1	.	.	.	.	1	18	.	.	1	1	1	.	.	5	189
OP .164	1	.	.	.	.	10	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	12
OP .166	1	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
OP .168	6	.	.	.	.	18	.	.	.	.	.	.	.	353	2	.	31	3	24	.	5	31	149	622

APPENDIX TABLE 8.—Station data: latitude and longitude, date of collection, time of day, depth of haul, and standardized haul factor.

STATION NUMBER	Latitude	Longitude (W)	Date - Month and Day of 1967	Hour *	Depth of Haul	Standardized Haul Factor
CRUISE 45						
45 .016	20 00.0N	118 57.2	VIII- 7	1416-D	204	3.16
45 .018	19 15.7N	118 56.0	VIII- 8	0127-N	214	3.41
45 .020	18 34.8N	118 59.0	VIII- 8	0835-D	197	3.02
45 .021	18 14.8N	118 58.3	VIII- 8	1216-D	212	3.54
45 .023	17 41.0N	119 01.8	VIII- 8	2110-N	214	3.48
45 .024	17 19.9N	119 01.5	VIII- 9	0115-N	213	2.95
45 .026	16 31.0N	119 02.8	VIII- 9	0904-D	175	2.51
45 .028	16 11.3N	119 03.3	VIII- 9	1349-D	179	2.80
45 .030	15 48.5N	119 05.3	VIII- 9	1830-NT	201	3.35
45 .032	15 10.5N	119 04.0	VIII-10	0020-N	194	3.15
45 .034	14 34.2N	119 03.2	VIII-10	0636-DT	210	3.44
45 .035	14 11.2N	119 03.8	VIII-10	1255-D	183	2.79
45 .037	13 47.0N	119 04.0	VIII-10	1755-DT	198	3.53
45 .039	13 00.0N	119 03.6	VIII-10	2400-N	193	3.12
45 .041	12 31.0N	119 03.5	VIII-11	0534-NT	203	3.83
45 .043	11 54.5N	119 02.7	VIII-11	1338-D	177	2.74
45 .044	11 29.0N	119 00.5	VIII-11	1820-NT	207	3.56
45 .046	10 51.7N	119 02.2	VIII-11	0005-N	216	3.78
45 .048	10 15.7N	119 03.3	VIII-12	0601-DT	177	2.67
45 .050	09 34.3N	119 03.0	VIII-12	1446-D	201	3.54
45 .051	09 10.2N	118 59.5	VIII-12	2051-N	201	3.31
45 .053	08 46.6N	118 58.3	VIII-13	0105-N	203	3.19
45 .054	08 28.2N	118 57.0	VIII-13	0716-D	209	3.38
45 .056	07 53.2N	118 51.3	VIII-13	1505-D	203	3.28
45 .058	07 24.8N	118 47.2	VIII-13	2030-N	191	2.97
45 .060	06 50.0N	118 55.3	VIII-14	0151-N	211	3.40
45 .063	05 55.5N	118 56.5	VIII-14	1053-D	209	3.46
45 .065	05 23.2N	118 51.2	VIII-14	1901-NT	224	3.90
45 .067	04 53.5N	119 06.8	VIII-14	2345-N	222	3.88
45 .071	04 06.0N	119 15.3	VIII-15	0730-D	219	3.61
45 .073	03 34.2N	119 14.7	VIII-15	1536-D	210	3.79
45 .078	02 48.5N	119 11.0	VIII-15	0001-N	201	3.71
45 .083	02 02.0N	119 03.2	VIII-16	0640-DT	213	3.64
45 .086	01 33.8N	119 02.2	VIII-16	1229-D	212	4.18
45 .090	00 57.2N	119 04.5	VIII-16	1901-NT	209	4.15
45 .094	00 23.5N	119 01.5	VIII-17	0051-N	201	3.81
45 .098	00 13.5S	118 58.0	VIII-17	0740-D	205	3.50
45 .102	00 56.0S	118 51.0	VIII-17	1253-D	171	1.96
45 .106	01 42.2S	118 43.8	VIII-17	1901-NT	202	3.02
45 .110	02 22.0S	118 43.5	VIII-17	0036-N	196	4.02
45 .114	03 12.0S	118 43.2	VIII-18	0800-D	212	3.26
45 .117	03 38.0S	118 48.5	VIII-18	1237-D	222	3.52
45 .121	04 14.3S	118 50.0	VIII-18	1841-NT	191	2.86
45 .125	04 45.8S	118 53.0	VIII-19	0243-N	216	4.20
45 .127	05 10.0S	118 54.5	VIII-19	0745-D	192	3.31
45 .129	05 41.8S	118 54.9	VIII-19	1231-D	215	3.91
45 .131	06 19.5S	118 58.0	VIII-19	1831-NT	205	3.83
45 .133	06 57.8S	119 01.5	VIII-19	2344-N	219	3.47
45 .135	07 26.8S	119 04.0	VIII-20	0535-NT	199	3.56
45 .137	08 12.0S	119 06.3	VIII-20	1125-D	214	3.79
45 .139	08 47.8S	119 00.0	VIII-20	1718-DT	200	4.19
45 .140	09 44.7S	118 59.0	VIII-21	0016-N	217	3.95
45 .163	09 56.9S	111 59.5	VIII-23	1153-D	217	3.82
45 .165	09 17.0S	111 59.0	VIII-23	1758-NT	196	3.46
45 .167	08 38.0S	111 57.4	VIII-23	2346-N	211	3.80
45 .169	08 01.3S	111 54.3	VIII-24	0641-D	208	3.76
45 .171	07 22.4S	111 51.0	VIII-24	1211-D	208	3.00
45 .173	06 47.5S	111 53.5	VIII-24	1750-NT	201	3.18
45 .175	06 01.6S	111 56.7	VIII-24	2356-N	218	3.84
45 .177	05 21.1S	111 59.5	VIII-25	0607-DT	197	3.33
45 .179	04 44.3S	112 02.0	VIII-25	NOT QUANTITATIVE		
45 .183	04 10.0S	112 05.8	VIII-25	1757-NT	195	4.20
45 .187	03 30.0S	112 01.5	VIII-25	2336-N	208	3.70
45 .191	02 56.3S	111 57.5	VIII-26	0611-DT	185	3.12
45 .194	02 17.9S	111 59.0	VIII-27	1752-NT	208	3.44
45 .198	01 30.7S	111 53.1	VIII-27	2341-N	196	3.50
45 .202	00 48.6S	111 46.6	VIII-28	0625-DT	181	2.86
45 .206	00 17.2S	111 56.5	VIII-28	1203-D	212	3.66
45 .283	00 04.2N	111 59.3	IX- 2	1321-D	174	2.49
45 .287	00 32.5N	112 04.5	IX- 2	1926-N	237	4.99
45 .289	00 53.8N	112 03.3	IX- 2	0001-N	194	4.02
45 .293	01 26.2N	112 01.4	IX- 3	0621-DT	202	3.81
45 .297	02 07.9N	111 58.3	IX- 3	1209-D	207	3.30
45 .301	02 47.3N	112 02.0	IX- 3	1811-NT	217	3.95
45 .305	03 25.8N	112 00.3	IX- 3	2335-N	209	3.60
45 .309	04 08.6N	111 56.3	IX- 4	0601-DT	222	3.82
45 .313	04 55.0N	111 53.5	IX- 4	1154-D	192	2.93
45 .316	05 58.7N	111 57.8	IX- 4	1746-NT	215	3.53
45 .319	07 01.8N	112 05.4	IX- 5	0620-D	217	3.35
45 .321	07 40.2N	112 06.8	IX- 5	1149-D	194	2.77
45 .323	08 18.0N	112 01.0	IX- 5	1756-NT	194	2.58
45 .325	09 01.8N	111 54.8	IX- 5	0007-N	156	2.02
45 .329	10 18.7N	111 44.0	IX- 6	1150-D	202	2.86
45 .331	10 49.5N	111 39.5	IX- 6	1805-NT	175	2.45
45 .333	11 27.0N	111 57.0	IX- 6	2341-N	156	2.52
45 .335	12 05.7N	112 09.0	IX- 7	0605-DT	215	3.95
45 .337	12 27.8N	111 36.1	IX- 7	1146-D	207	3.17
45 .339	12 58.4N	111 14.3	IX- 7	1757-NT	216	3.11
45 .341	13 33.4N	110 50.0	IX- 7	0006-N	187	3.01
45 .343	13 56.3N	110 34.0	IX- 8	0805-D	193	2.79
45 .344	14 12.5N	110 23.0	IX- 8	1146-D	144	1.80
45 .345	14 38.2N	109 37.1	IX- 8	1841-N	135	1.71
45 .348	14 57.4N	109 04.3	IX- 8	2345-N	199	3.16
45 .350	15 16.0N	108 37.5	IX- 9	0535-DT	206	3.22
45 .352	15 45.0N	108 08.5	IX- 9	1141-D	217	3.56
45 .356	16 53.0N	107 03.0	IX- 9	2334-N	186	2.87
45 .358	17 20.5N	106 29.8	IX-10	0536-DT	208	3.40
45 .360	18 01.0N	105 41.0	IX-10	1248-D	216	3.68
45 .362	18 16.5N	105 20.5	IX-10	1828-N	199	3.27
45 .365	18 48.5N	104 44.0	IX-10	2351-N	207	3.48
45 .367	19 00.0N	104 50.0	IX-13	1455-D	212	3.57
45 .369	19 05.3N	105 09.2	IX-13	1925-N	209	3.53
45 .371	19 12.5N	105 40.5	IX-14	0024-N	203	3.33
45 .373	19 19.5N	106 13.8	IX-14	0601-D	221	3.63
45 .375	19 34.3N	106 57.2	IX-14	1148-D	184	2.74
45 .377	19 36.2N	107 37.6	IX-14	1810-NT	195	3.31
45 .379	19 38.5N	108 24.0	IX-14	2351-N	204	3.27
45 .381	19 41.7N	109 08.0	IX-15	0520-DT	192	2.82

APPENDIX TABLE 8.—Station data: latitude and longitude, date of collection, time of day, depth of haul, and standardized haul factor.—*Continued.*

STATION NUMBER	Latitude	Longitude (W)	Date - Month and Day of 1967	Hour *	Depth of Haul	Standardized Haul Factor
45 .383	19 48.0N	109 56.7	IX-15	1126-D	212	3.37
45 .385	19 53.0N	110 46.2	IX-15	1755-NT	200	3.07
45 .387	19 58.7N	111 25.2	IX-15	2328-N	206	3.22
CRUISE	46					
46 .002	16 14.0N	100 27.5	VIII-16	1801-NT	214	3.53
46 .004	15 48.5N	100 53.8	VIII-17	0032-N	195	2.60
46 .006	15 28.0N	101 18.0	VIII-17	0730-D	209	3.31
46 .007	15 13.0N	101 35.5	VIII-17	1150-D	262	3.91
46 .009	14 50.5N	102 02.0	VIII-17	1750-NT	202	2.98
46 .011	14 19.2N	102 38.0	VIII-17	2352-N	198	2.90
46 .013	13 56.0N	103 01.0	VIII-18	0541-D	211	3.39
46 .015	13 20.0N	103 27.0	VIII-18	1141-D	211	3.34
46 .017	12 53.0N	103 56.0	VIII-18	1741-NT	214	3.51
46 .019	12 16.0N	104 32.0	VIII-19	0052-N	208	2.99
46 .020	12 03.0N	104 46.0	VIII-19	0601-D	217	3.45
46 .022	11 26.0N	105 04.0	VIII-19	1136-D	192	2.39
46 .024	10 46.0N	105 08.0	VIII-19	1748-NT	216	3.37
46 .026	10 03.5N	105 02.0	VIII-19	2351-N	195	3.10
46 .028	09 31.0N	105 05.0	VIII-20	0551-D	211	3.65
46 .030	08 43.0N	105 03.0	VIII-20	1159-D	187	3.35
46 .032	08 07.0N	105 00.0	VIII-20	1733-NT	215	3.61
46 .034	07 22.0N	104 57.0	VIII-20	2351-N	216	3.58
46 .036	06 50.0N	104 54.0	VIII-21	0551-DT	126	1.85
46 .038	06 13.0N	104 47.0	VIII-21	1208-D	208	3.45
46 .040	05 39.0N	104 53.0	VIII-21	1749-NT	216	3.59
46 .042	04 52.0N	105 00.0	VIII-22	0041-N	208	3.57
46 .044	04 34.0N	105 02.0	VIII-22	0551-DT	214	3.56
46 .046	03 57.0N	105 04.0	VIII-22	1153-D	204	3.29
46 .048	03 33.0N	105 11.0	VIII-22	1748-NT	213	3.58
46 .050	02 50.0N	105 16.0	VIII-23	0011-N	204	3.35
46 .052	02 28.0N	105 15.0	VIII-23	0551-DT	210	3.28
46 .054	01 47.0N	105 12.0	VIII-23	1227-D	157	2.05
46 .055	01 29.0N	105 14.0	VIII-23	1809-N	159	2.09
46 .057	00 53.0N	105 19.0	VIII-23	2346-N	112	1.18
46 .059	00 24.0N	105 25.0	VIII-24	0606-D	84	.84
46 .061	00 20.0S	105 20.0	VIII-24	1159-D	161	2.36
46 .063	00 42.0S	105 15.0	VIII-24	1738-NT	219	3.73
46 .065	01 34.0S	105 08.0	VIII-25	0001-N	194	3.09
46 .067	02 00.0S	105 01.0	VIII-25	0541-DT	202	3.49
46 .069	02 47.7S	104 48.0	VIII-25	1204-D	261	3.43
46 .071	03 17.0S	104 55.0	VIII-25	1750-NT	199	3.16
46 .075	04 27.0S	105 00.0	VIII-28	1203-D	165	2.34
46 .077	05 01.0S	105 03.0	VIII-28	1750-NT	219	3.49
46 .079	01 04.0S	098 03.0	VIII-31	0321-N	170	2.19
46 .082	00 10.9S	098 02.0	VIII-31	1218-D	196	3.06
46 .084	00 10.0N	098 03.0	VIII-31	1808-N	208	3.41
46 .086	00 47.0N	098 04.0	IX- 1	0001-N	179	2.64
46 .088	01 12.0N	098 04.0	IX- 1	0546-D	217	3.96
46 .090	01 55.0N	098 05.0	IX- 1	1200-D	170	2.45
46 .092	02 21.0N	098 07.0	IX- 1	1729-NT	210	3.49
46 .094	03 08.0N	098 12.0	IX- 2	0001-N	196	2.97
46 .096	03 32.5N	098 14.5	IX- 2	0531-D	198	3.12
46 .098	04 20.0N	098 00.0	IX- 2	1208-D	198	3.14
46 .100	04 48.0N	098 04.0	IX- 2	1745-N	223	3.50
46 .102	05 36.0N	097 54.0	IX- 2	2341-N	210	3.21
46 .104	06 09.0N	097 45.0	IX- 3	0611-D	199	2.81
46 .106	06 56.4N	097 48.0	IX- 3	1211-D	213	3.45
46 .108	07 35.0N	098 00.0	IX- 3	1742-N	215	3.29
46 .110	08 25.0N	097 56.0	IX- 3	2351-N	209	3.94
46 .112	08 57.5N	097 51.0	IX- 4	0411-NT	212	3.93
46 .114	09 45.0N	097 48.0	IX- 4	1206-D	216	3.53
46 .116	10 25.0N	098 01.0	IX- 4	1742-N	221	3.86
46 .118	11 02.5N	098 04.5	IX- 5	0011-N	204	3.08
46 .120	11 28.0N	098 07.0	IX- 5	0422-NT	218	3.44
46 .122	12 17.9N	097 59.0	IX- 5	1238-D	201	3.10
46 .124	12 53.0N	098 03.0	IX- 5	1734-NT	220	3.68
46 .126	13 41.0N	098 03.0	IX- 6	0021-N	206	3.16
46 .128	14 09.0N	098 01.0	IX- 6	0416-NT	225	3.82
46 .130	14 56.0N	097 57.0	IX- 6	1211-D	199	3.11
46 .132	15 38.0N	098 01.0	IX- 6	1740-NT	213	2.60
46 .134	13 12.5N	091 51.0	IX-15	1141-D	214	3.54
46 .135	12 40.0N	092 03.0	IX-15	1701-NT	218	3.63
46 .137	11 48.0N	092 03.0	IX-15	2340-N	206	3.31
46 .139	11 08.0N	091 58.0	IX-16	0418-DT	199	2.90
46 .141	10 19.2N	091 54.0	IX-16	1151-D	204	3.23
46 .143	09 42.0N	091 58.0	IX-16	1732-N	218	3.57
46 .145	08 55.0N	092 02.0	IX-16	2349-N	177	2.55
46 .147	08 28.0N	092 05.0	IX-17	0419-DT	170	2.45
46 .149	07 44.0N	092 08.0	IX-17	1141-D	182	2.74
46 .151	07 01.0N	092 08.0	IX-17	1731-N	204	3.19
46 .153	06 13.0N	092 03.0	IX-17	2338-N	183	2.86
46 .155	05 40.0N	091 58.0	IX-18	0418-DT	224	3.88
46 .157	04 54.0N	091 52.0	IX-18	1141-D	205	3.17
46 .159	04 19.0N	091 56.0	IX-18	1731-N	219	3.58
46 .161	03 34.0N	091 56.0	IX-18	2339-N	217	3.47
46 .163	02 59.0N	092 00.0	IX-19	0418-DT	228	3.67
46 .165	02 13.0N	092 07.0	IX-19	1141-D	195	2.64
46 .167	01 39.0N	092 04.0	IX-19	1748-N	189	2.48
46 .169	00 54.0N	092 04.0	IX-20	0001-N	156	2.10
46 .171	00 23.0N	092 04.0	IX-20	0418-DT	216	3.71
46 .173	00 14.2S	092 03.0	IX-20	1141-D	194	2.95
46 .175	00 47.0S	092 03.0	IX-20	1731-N	207	3.45
46 .177	01 32.0S	092 06.0	IX-20	2339-N	197	3.33
46 .179	02 03.5S	092 07.0	IX-21	0416-DT	159	2.44
46 .181	02 49.6S	092 10.0	IX-21	1141-D	128	1.57
46 .183	03 27.0S	092 08.5	IX-21	1731-N	171	2.45
46 .185	04 09.5S	092 07.0	IX-21	2337-N	176	3.12
46 .187	04 46.0S	092 06.0	IX-22	0418-DT	222	3.42
46 .189	05 27.0S	092 05.0	IX-22	1211-D	205	3.42
CRUISE	47					
47 .001	05 36.0N	077 51.0	VII-31	1722-N	181	2.86
47 .005	06 03.0N	078 20.0	VIII- 1	2319-N	214	3.53
47 .008	06 24.0N	078 41.0	VIII- 2	0213-NT	164	2.33
47 .011	06 50.0N	079 16.0	VIII- 2	1046-D	175	2.60
47 .019	06 58.0N	080 54.0	VIII- 2	2306-N	156	1.88
47 .022	06 21.0N	080 41.0	VIII- 3	0331-DT	215	3.66
47 .025	05 41.0N	080 32.0	VIII- 3	0943-D	203	3.10
47 .028	04 51.0N	080 15.0	VIII- 3	1840-N	175	2.42

APPENDIX TABLE 8.—Station data: latitude and longitude, date of collection, time of day, depth of haul, and standardized haul factor.—*Continued.*

STATION NUMBER	Latitude	Longitude (W)	Date - Month and Day of 1967	Hour *	Depth of Haul	Standardized Haul Factor
47 .032	04 01.0N	079 54.0	VIII- 4	0136-N	195	2.77
47 .034	03 31.0N	079 41.0	VIII- 4	0730-D	196	2.77
47 .035	02 57.0N	079 39.0	VIII- 4	1351-D	205	3.13
47 .040	01 41.0N	079 22.0	VIII- 4	2010-N	202	2.69
47 .049	01 00.0N	082 00.0	VIII- 5	1239-D	215	3.67
47 .053	00 18.0N	081 57.0	VIII- 5	2104-N	193	2.91
47 .057	00 22.0S	082 00.0	VIII- 6	0211-N	210	3.38
47 .061	01 11.0S	082 02.0	VIII- 6	0748-D	193	3.09
47 .065	01 46.0S	081 58.0	VIII- 6	1333-D	202	2.48
47 .069	02 27.0S	081 50.0	VIII- 6	2006-N	148	1.94
47 .070	03 06.0S	082 01.0	VIII- 9	2103-N	193	2.53
47 .074	03 58.0S	082 02.0	VIII-10	0305-NT	203	3.35
47 .078	04 39.0S	082 03.0	VIII-10	NOT QUANTITATIVE		
47 .082	05 21.0S	082 02.5	VIII-10	1358-D	204	3.09
47 .086	06 04.0S	082 00.0	VIII-10	1941-N	208	3.06
47 .090	06 47.0S	081 58.0	VIII-11	0211-N	217	3.79
47 .094	07 28.0S	081 56.5	VIII-11	0756-D	218	3.40
47 .097	08 11.0S	082 01.0	VIII-11	1314-D	205	3.20
47 .099	08 48.0S	082 04.0	VIII-11	2111-N	214	3.39
47 .101	09 29.0S	082 05.0	VIII-12	0211-N	220	3.63
47 .103	10 09.0S	082 09.0	VIII-12	0751-D	213	3.51
47 .105	10 02.0S	081 34.0	VIII-12	1246-D	204	3.20
47 .107	09 50.0S	080 53.0	VIII-12	2042-N	196	2.81
47 .109	09 35.0S	080 15.0	VIII-13	0215-N	205	3.23
47 .113	09 22.0S	079 39.0	VIII-13	0733-D	216	3.61
47 .124	12 13.0S	077 39.0	VIII-16	1340-D	200	3.05
47 .128	12 29.0S	078 04.0	VIII-16	2216-N	200	3.00
47 .132	12 44.0S	078 52.0	VIII-17	0304-NT	213	2.50
47 .134	12 56.0S	079 28.0	VIII-17	0746-D	211	3.27
47 .137	13 10.0S	080 13.0	VIII-17	1341-D	210	3.17
47 .139	13 27.0S	081 01.0	VIII-17	1922-N	209	3.24
47 .141	13 38.0S	081 45.0	VIII-18	0107-N	211	3.38
47 .143	13 58.0S	082 25.0	VIII-18	0719-D	213	3.53
47 .145	14 18.0S	083 05.0	VIII-18	1232-D	213	3.47
47 .147	14 33.0S	083 41.0	VIII-18	2121-N	217	3.70
47 .149	14 43.0S	084 21.0	VIII-19	0235-N	214	3.61
47 .151	14 56.0S	085 00.0	VIII-19	0806-D	216	3.75
47 .153	14 17.0S	085 03.0	VIII-19	1259-D	210	3.53
47 .155	13 35.0S	085 00.0	VIII-19	1857-N	214	3.60
47 .157	12 44.0S	085 07.0	VIII-20	0335-NT	209	3.38
47 .159	12 06.5S	084 59.0	VIII-20	0756-D	214	3.82
47 .162	11 30.0S	085 01.3	VIII-20	1349-D	207	3.60
47 .164	10 43.2S	085 04.0	VIII-20	2146-N	215	3.65
47 .166	10 01.0S	085 05.3	VIII-21	0258-NT	211	3.57
47 .168	09 16.8S	085 07.3	VIII-21	0817-D	209	4.06
47 .171	08 35.0S	085 02.3	VIII-21	1325-D	212	3.61
47 .173	07 54.8S	085 06.0	VIII-21	1945-N	216	3.61
47 .175	07 16.0S	085 07.3	VIII-22	0123-N	211	3.80
47 .177	06 35.0S	085 08.5	VIII-22	0754-D	217	2.79
47 .179	05 49.7S	085 00.0	VIII-22	1301-D	221	4.39
47 .181	05 17.0S	085 01.0	VIII-22	2101-N	213	3.85
47 .185	04 28.5S	085 00.0	VIII-23	0309-NT	212	3.82
47 .189	03 51.0S	085 01.0	VIII-23	0837-D	211	3.57
47 .193	02 58.8S	085 01.0	VIII-23	1456-DT	220	4.15
47 .197	02 10.0S	085 03.0	VIII-23	2055-N	222	3.97
47 .201	01 26.0S	085 03.5	VIII-24	0249-NT	209	3.64
47 .205	00 39.5S	085 04.0	VIII-24	0835-D	207	3.61
47 .213	00 47.0N	084 55.0	VIII-24	2141-N	192	3.03
47 .217	01 31.0N	084 55.0	VIII-25	0326-NT	211	3.51
47 .221	02 08.0N	084 57.2	VIII-25	0836-D	211	3.44
47 .225	02 47.0N	084 58.5	VIII-25	1500-DT	200	3.22
47 .229	03 33.0N	084 54.0	VIII-25	2053-N	209	3.63
47 .233	04 21.0N	084 49.0	VIII-26	0248-NT	207	3.26
47 .237	05 06.5N	084 45.0	VIII-26	0835-D	213	3.76
47 .240	05 41.0N	084 56.5	VIII-26	1336-D	205	3.51
47 .242	06 21.0N	084 54.5	VIII-26	1957-N	146	2.10
47 .244	06 59.0N	084 54.0	VIII-27	0156-N	207	3.58
47 .246	07 42.5N	085 04.0	VIII-27	0825-D	204	3.52
47 .250	08 26.5N	085 05.0	VIII-27	1430-D	210	3.61
47 .254	08 56.5N	085 01.0	VIII-27	1946-N	224	4.26
47 .258	09 26.5N	084 52.0	VIII-28	0055-N	213	3.27
47 .268	11 58.0N	088 02.0	VIII-31	0919-D	191	3.30
47 .272	11 20.8N	088 00.0	VIII-31	1441-D	195	3.10
47 .276	10 54.0N	088 10.0	VIII-31	2201-N	183	3.20
47 .278	10 21.0N	088 18.0	IX- 1	0345-DT	219	3.69
47 .280	09 44.5N	088 14.0	IX- 1	0941-D	201	3.46
47 .283	09 04.0N	088 04.0	IX- 1	1512-DT	209	3.80
47 .286	08 15.0N	087 52.0	IX- 1	2117-N	215	3.81
47 .288	07 29.0N	087 44.0	IX- 2	0330-NT	215	3.91
47 .290	06 47.0N	087 57.0	IX- 2	0949-D	207	3.32
47 .292	06 20.0N	087 57.0	IX- 2	1514-DT	207	3.48
47 .295	05 16.0N	087 57.0	IX- 2	2201-N	208	3.53
47 .297	04 38.0N	087 57.0	IX- 3	2246-N	213	3.39
47 .301	04 00.0N	088 02.0	IX- 4	0353-DT	212	3.50
47 .304	03 22.0N	088 04.0	IX- 4	0847-D	211	3.46
47 .306	02 44.8N	087 59.0	IX- 4	1407-D	211	3.52
47 .310	02 02.0N	088 03.0	IX- 4	2027-N	204	3.32
47 .314	01 18.0N	088 06.0	IX- 5	0201-N	220	3.95
47 .318	00 33.5N	088 02.0	IX- 5	0829-D	216	3.90
47 .322	00 13.5S	088 07.0	IX- 5	1446-D	177	2.37
47 .326	00 59.0S	088 06.5	IX- 5	2053-N	150	2.01
47 .330	01 44.5S	088 08.2	IX- 6	0255-NT	185	3.10
47 .334	02 23.5S	088 02.3	IX- 6	0837-D	222	4.51
47 .338	03 04.0S	088 03.5	IX- 6	1421-D	212	4.21
47 .342	03 47.5S	088 03.5	IX- 6	2139-N	215	4.06
47 .345	04 29.0S	087 57.0	IX- 7	0334-NT	209	3.77
47 .349	05 09.5S	088 02.0	IX- 7	0923-D	217	3.95
47 .351	05 53.0S	087 59.0	IX- 7	1513-DT	174	2.60
47 .354	06 36.5S	087 59.0	IX- 7	2057-N	207	3.35
47 .357	07 18.0S	088 01.0	IX- 8	0207-N	205	3.32
47 .359	08 07.0S	088 03.0	IX- 8	0846-D	211	3.65
47 .362	08 55.0S	088 04.0	IX- 8	1421-D	206	3.34
47 .364	09 40.0S	088 02.0	IX- 8	2011-N	163	2.93
47 .367	10 22.0S	088 02.0	IX- 9	0207-N	209	3.23
47 .369	11 02.0S	087 58.0	IX- 9	0756-D	215	3.61
47 .371	11 48.0S	088 00.0	IX- 9	1346-D	205	3.18
47 .373	12 31.0S	088 03.0	IX- 9	2136-N	225	4.02
47 .376	13 13.8S	088 01.0	IX-10	0311-NT	209	3.40
47 .379	13 57.0S	087 57.0	IX-10	0902-D	211	3.69
47 .382	14 47.0S	087 59.0	IX-10	1451-DT	205	3.26

APPENDIX TABLE 8.—Station data: latitude and longitude, date of collection, time of day, depth of haul, and standardized haul factor.—*Continued.*

STATION NUMBER	Latitude	Longitude (W)	Date - Month and Day of 1967	Hour *	Depth of Haul	Standardized Haul Factor
47 .415	11 06.5S	095 01.5	IX-13	0745-D	211	3.14
47 .430	09 27.0S	094 59.0	IX-14	2100-N	209	3.04
47 .432	10 14.7S	095 02.0	IX-15	0253-N	229	3.41
47 .436	08 32.0S	095 01.5	IX-15	1225-D	237	4.51
47 .438	07 39.5S	095 08.5	IX-15	2040-N	214	3.80
47 .440	06 41.0S	095 09.0	IX-16	0258-N	256	4.84
47 .443	05 55.0S	095 08.3	IX-16	0908-D	249	4.26
47 .446	05 01.5S	095 05.5	IX-16	1510-D	173	2.99
47 .450	04 14.0S	095 01.0	IX-16	2036-N	216	4.54
47 .454	03 27.3S	095 00.5	IX-17	0242-N	215	4.08
47 .458	02 40.5S	095 00.5	IX-17	0817-D	161	2.31
47 .462	01 54.0S	095 04.0	IX-17	1356-D	180	2.68
47 .466	01 01.0S	095 08.5	IX-17	2101-N	210	5.19
47 .470	00 24.3S	095 09.2	IX-18	0424-DT	166	1.98
47 .478	01 05.2N	094 57.7	IX-19	1601-DT	205	3.43
47 .486	02 32.5N	094 42.0	IX-19	0313-NT	205	3.00
47 .490	03 16.3N	094 40.8	IX-19	0835-D	222	3.61
47 .494	03 58.0N	094 59.0	IX-19	1349-D	216	3.65
47 .498	04 44.0N	094 55.0	IX-19	2207-N	213	3.51
47 .501	05 36.0N	094 55.5	IX-20	0319-NT	206	3.90
47 .504	06 26.5N	094 58.5	IX-20	0853-D	219	3.39
47 .507	07 19.0N	094 57.5	IX-20	1427-D	209	3.19
47 .509	08 05.0N	095 02.0	IX-20	1955-N	207	2.87
47 .511	08 56.5N	095 04.0	IX-21	0142-N	200	2.83
47 .513	09 49.0N	095 05.0	IX-21	0722-D	193	2.44
47 .515	10 45.5N	095 04.0	IX-21	1321-D	217	3.58
47 .517	11 36.0N	095 00.5	IX-21	2101-N	211	3.48
47 .520	12 33.2N	094 57.0	IX-22	0249-N	205	3.13
47 .523	13 16.0N	095 00.0	IX-22	0748-D	210	3.72
47 .525	14 11.0N	095 01.0	IX-22	1330-D	204	2.92
47 .527	15 00.3N	094 59.0	IX-22	1858-N	204	3.01
CRUISE OP						
OP .001	09 17.4S	079 41.9	XI-14	0228-NT	198	3.00
OP .002	09 41.9S	080 28.4	XI-14	0836-D	255	3.88
OP .003	09 53.6S	080 50.6	XI-14	1231-D	206	3.06
OP .005	10 14.0S	081 26.0	XI-14	1818-N	192	3.41
OP .007	10 40.0S	082 20.5	XI-14	0008-N	191	3.28
OP .009	10 58.4S	082 59.4	XI-15	0626-D	191	2.63
OP .011	11 26.2S	083 51.6	XI-15	1216-D	179	2.87
OP .013	11 58.1S	084 54.6	XI-15	1948-N	205	2.68
OP .015	11 18.9S	084 54.4	XI-15	0001-N	194	3.37
OP .017	10 31.0S	084 54.0	XI-16	NOT QUANTITATIVE		
OP .019	09 40.5S	084 52.8	XI-16	1225-D	214	3.98
OP .021	08 57.1S	084 52.7	XI-16	1827-N	240	4.09
OP .023	07 57.8S	084 53.6	XI-16	0008-N	193	3.38
OP .025	07 13.1S	084 52.7	XI-17	0611-D	205	3.41
OP .027	06 07.8S	084 55.1	XI-17	1153-D	206	3.65
OP .029	05 15.9S	084 53.3	XI-17	1801-N	208	3.32
OP .032	04 12.9S	084 55.8	XI-17	0002-N	216	4.01
OP .036	03 34.3S	084 56.1	XI-18	0601-D	230	4.03
OP .040	02 30.7S	084 57.9	XI-18	1141-D	201	3.44
OP .044	01 57.0S	084 58.0	XI-18	1722-N	218	4.19
OP .048	00 41.1S	084 57.9	XI-18	2331-N	174	2.77
OP .052	00 04.1N	084 57.9	XI-19	0619-D	204	3.60
OP .056	00 17.8S	085 37.8	XI-19	1141-D	223	4.16
OP .060	00 30.6S	086 12.8	XI-19	1753-N	209	3.75
OP .064	00 54.2S	087 09.3	XI-19	2329-N	227	4.29
OP .068	01 10.4S	087 52.2	XI-20	0532-D	216	3.78
OP .072	01 37.8S	088 47.9	XI-20	1123-D	216	3.66
OP .076	01 56.8S	089 26.0	XI-20	1743-N	213	3.87
OP .080	02 20.7S	090 24.7	XI-20	2331-N	226	3.99
OP .084	02 36.6S	091 08.8	XI-21	0518-D	211	4.17
OP .088	02 59.5S	092 02.8	XI-21	1056-D	216	3.00
OP .092	02 11.6S	092 06.1	XI-21	1747-N	211	3.73
OP .096	01 07.5S	092 03.9	XI-21	2329-N	219	3.99
OP .100	00 24.0S	092 05.0	XI-22	0527-D	199	2.89
OP .104	00 46.5N	092 05.8	XI-22	1140-D	214	3.63
OP .108	01 24.8N	092 08.2	XI-22	1730-N	215	4.07
OP .112	02 35.5N	092 03.7	XI-22	2330-N	216	3.96
OP .116	03 15.0N	092 00.3	XI-23	0517-D	205	3.63
OP .120	04 23.6N	091 58.8	XI-23	1139-D	217	3.60
OP .124	05 08.7N	091 56.7	XI-23	1733-N	203	3.50
OP .128	06 08.4N	091 58.9	XI-23	2333-N	203	3.40
OP .132	06 48.3N	092 00.4	XI-24	0515-D	184	2.92
OP .136	07 57.4N	092 02.8	XI-24	1157-D	225	4.03
OP .138	08 12.3N	092 03.2	XI-24	1716-N	193	3.10
OP .155	09 03.1N	092 00.4	XI-25	1153-D	216	3.78
OP .160	10 14.9N	091 59.5	XI-25	2335-N	203	3.51
OP .162	11 09.5N	092 00.3	XI-26	0517-D	181	3.09
OP .164	11 43.5N	091 59.6	XI-26	1242-D	216	4.24
OP .166	12 24.0N	092 01.1	XI-26	1713-N	204	3.40
OP .168	13 21.2N	091 59.4	XI-26	2157-N	212	3.83

DESCRIPTION OF BLACK SEA BASS, *CENTROPRISTIS STRIATA* (LINNAEUS), LARVAE AND THEIR OCCURRENCES NORTH OF CAPE LOOKOUT, NORTH CAROLINA, IN 1966

ARTHUR W. KENDALL, JR.[1]

ABSTRACT

Larvae of black sea bass collected during RV *Dolphin* ichthyoplankton surveys of the mid-Atlantic continental shelf are described. Development of most meristic characters occurs between 6 and 10 mm standard length. The larvae are identified by characteristic ventral pigment patterns, body shape, meristic counts, and lack of extensive armature. The 147 larvae were taken during cruises from June to November 1966, from 4 to 82 km from shore. They were found in tows from the surface to 33 m in water varying in surface temperature from 14.3° to 28.0°C and surface salinity from 30.3 to 34.6‰.

Black sea bass are of considerable economic importance and occur along most of the Atlantic coast of the United States. Although they were first studied in the late 1800's little is reported on their early life history. Spawning is reported to take place in May off North Carolina and in mid-May and June off New Jersey and southern New England (Bigelow and Schroeder, 1953; Miller, 1959). Wilson (1891) described their embryology as part of an incomplete monograph on the species but did not describe the larvae or provide diagnostic characteristics to identify eggs. Hoff (1970) figured a black sea bass egg and prolarva from artificially reared specimens but gave no written description (Figure 1). The eggs are pelagic, clear, round, and 0.9 to 1.0 mm in diameter. They have a smooth shell, narrow perivitelline space, and a single oil globule. They hatch in 75 hr at 16°C and in 38 hr at 23°C (Wilson, 1891; Hoff, 1970). The larvae remain inadequately described although Pearson (1941) identified specimens collected at the mouth of Chesapeake Bay as black sea bass by comparing them with a known series from southern New England using the ventral pigment pattern and fin ray counts. Apparently Merriman and Sclar (1952) had access to the same or similar specimens as Pearson because they pointed out differences between black sea bass and silver hake, *Merluccius bilinearis*, larvae. O. E. Sette's notes, made in connection with his work on Atlantic mackerel, *Scomber scombrus*, early life history contained a mention of black sea bass in a description of bluefish, *Pomatomus saltatrix*, larvae. Larvae of black sea bass have been identified from other collections of ichthyoplankton along the east coast of North America (Perlmutter, 1939; Herman, 1963) with no reference to means of identification. Figures of juveniles, ranging from 39 to 58 mm total length (TL), are shown in Bean (1888), Hildebrand and Schroeder (1928), and Fowler (1945) and reproduced here (Figure 2).

Three species of *Centropristis* occur along the Atlantic coast; *C. striata* is the most widespread and occurs from the Gulf of Maine to the Florida Keys (Miller, 1959). Rock sea bass, *C. philadelphica*, occurs along the Atlantic coast south of Chesapeake Bay, and bank sea bass, *C. ocyurus*, is found generally offshore south of Cape Hatteras. All three species also occur in the Gulf of Mexico, *C. striata* as the subspecies *C. s. melana* (southern sea bass). Black sea bass generally occur over hard bottoms and migrate along the middle Atlantic coast shoreward and northward in summer and offshore and south in

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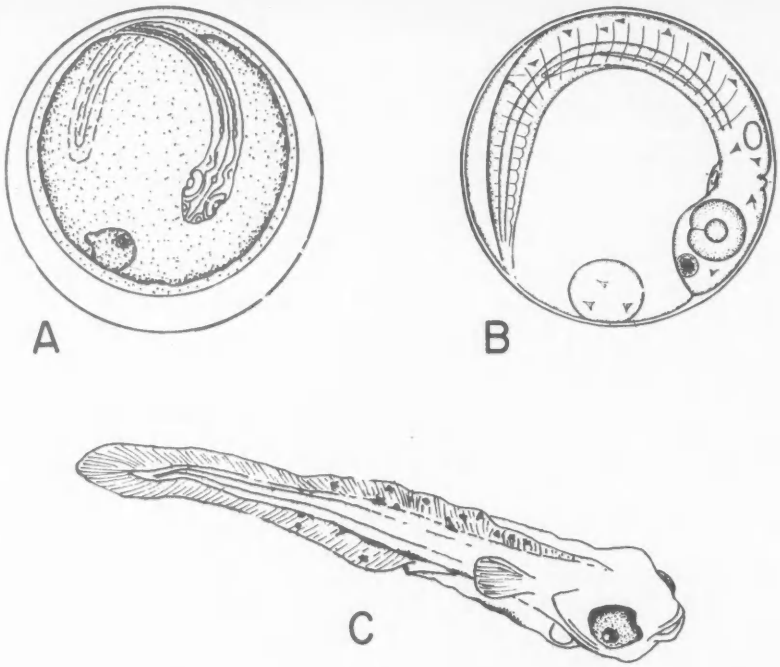

FIGURE 1.—Previously illustrated black sea bass eggs and prolarva. A) egg, 23 hr after fertilization at 23°C, from Hoff (1970, Figure 8); B) egg, 65 hr after fertilization at 16°C, from Wilson (1891, Figure 151); C) prolarva, 54 hr after hatching at 23°C, 2.01 mm TL, from Hoff (1970, Figure 9).

winter. *C. striata* is the only serranid expected to spawn on the continental shelf between Chesapeake Bay and Cape Cod, Mass. (Miller, 1959). Among east coast serranids the unique fin element counts for *Centropristis* for dorsal (X, 11) and anal (III, 7) fins allowed me to determine that I had larvae of this genus. The modal pectoral fin ray count of 18 for black sea bass is distinctive among *Centropristis* and seen on larger larvae. The pigment patterns on larger larvae, whose fin complements were complete, were seen in smaller larvae which appeared to be developing the meristic characters of black sea bass. This was the rationale for identifying the larvae described here as *Centropristis striata*.

On five ichthyoplankton surveys by the RV *Dolphin* between June and November 1966, we collected larval black sea bass at stations between Barnegat Bay, N.J., and Cape Lookout, N.C. This paper describes these larvae and their occurrences.

PROCEDURES

Collecting methods and hydrographic data from the 1965-66 RV *Dolphin* ichthyoplankton survey are reported in detail by Clark et al. (1969). Gulf V plankton tows were taken at 92 stations on eight cruises between Cape Cod, Mass., and Cape Lookout, N.C. The oblique tows covered 4.6 km with one net fishing from the surface to 15 m and, simultaneously, a second, from 18 to 33 m. Samples fixed in 5% buffered

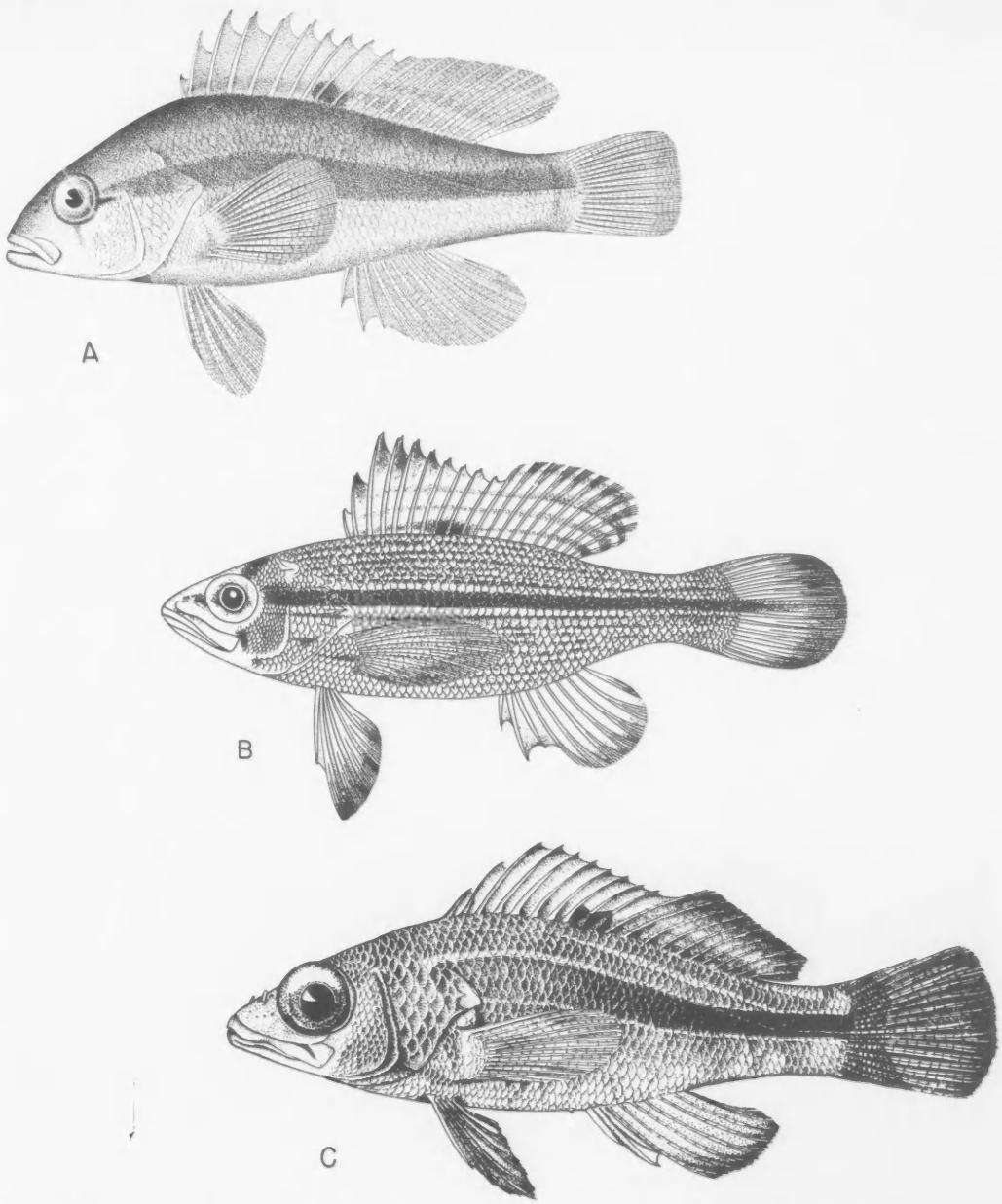

FIGURE 2.—Previously illustrated juvenile black sea bass. A) 39 mm SL, from Bean (1888, Figure 12); B) 42.4 mm SL, from Fowler (1945, Figure 263); C) 58 mm TL (?) from Hildebrand and Schroeder (1928, Figure 144).

Formalin[2] were returned to the laboratory where fish eggs and larvae were removed.

Black sea bass larvae were identified using criteria described, separated from the rest of the larvae in the *Dolphin* collections, counted and measured in standard length (SL). Black sea bass eggs are not well described, and several of their characteristics apply to many other species, so they were not identified in our samples. Other young black sea bass examined included one larva (13.0 mm SL)[3] and several juveniles (37-73 mm SL).[4] Body proportions were measured to the nearest 0.1 mm on selected larvae in Formalin on a depression slide with an ocular micrometer. The base points for larval measurements approximate those used by Ahlstrom and Ball (1954) except body depth, which was measured at the junction of the cleithra, and standard length, measured to the distal ends of the hypurals when formed. Base points for measurements of juveniles follow Hubbs and Lagler (1958). We determined meristic counts on selected specimens lightly stained with alizarin red. Osteological examination was made from specimens cleared and stained following Clothier's (1950) method. Michael P. Fahay illustrated the larvae (Figures 3 and 9).

DESCRIPTION OF LARVAE

In the following description, features useful in identifying black sea bass larvae are emphasized rather than those demonstrating general teleostean development. The approach follows Ahlstrom and Ball (1954) in that each feature is at once traced through its development within the size range (2-13 mm) of the available larvae. Four areas of development are described: armature, body shape, meristic characters, and pigment patterns. Stages of development of black sea bass larvae are illustrated in Figure 3.

[2] Reference to trade names in the publication does not imply endorsement of commercial products by the National Marine Fisheries Service.

[3] Collected on October 5, 1967, at Corson Inlet, N.J., by Walter S. Murawski, Jr., New Jersey Department of Conservation and Economic Development.

[4] Inshore seining collections of fish from New Jersey taken by Dr. Albert E. Parr.

ARMATURE

Among larvae of serranids which have been described there is diversity of development of armature. Species of *Epinephelus* develop anterior dorsal and pelvic spines nearly as long as the larva. These spines are barbed and serrated. Preopercular spines are also well developed (Sparta, 1935; Mito, Ukawa, and Higuchi, 1967; Presley, 1970). Larvae of other genera are less ornate and the relative length of fin spines is near that of the adults in some (Bertolini, 1933). Black sea bass larvae are among the serranids with little development of armature. No fin spines are either serrated or pronounced. Pelvic fin spines do not reach the vent; the dorsal and anal fin spines are shorter than the rays. Four to seven short, widely spaced spines are present on the posterior margins of the preopercle and opercle on larvae longer than 5 mm. The three small spines on the opercular flap of the adult form at 8 mm (Figure 3C). Preopercular serrations characteristic of the adult develop early in the juvenile stage.

BODY SHAPE

Changes from larval to adult body form take place over a narrow size range, and the extent of development among fish with similar standard lengths varies. Some body proportions of juvenile and adult black sea bass given by Miller (1959) are compared to those of the developing larvae in this section and in Figures 4 to 6. Between 2 and 5 mm the body proportions remain fairly constant with a slight increase in snout and eye length, and body and caudal peduncle depth, relative to standard length. Most head and body proportions increase significantly between 5 and 6 mm then level off as they approach those of the adult. Caudal peduncle depth and total length, relative to standard length, continue to increase through the larval stage as the caudal fin develops. Body depth, head length, and preanal length proportions increase through the juvenile stage. The adult black sea bass is robust with a large terminal mouth and large head. The back is slightly elevated anteriorly. The dorsal fins are contiguous and the pectorals and pelvics

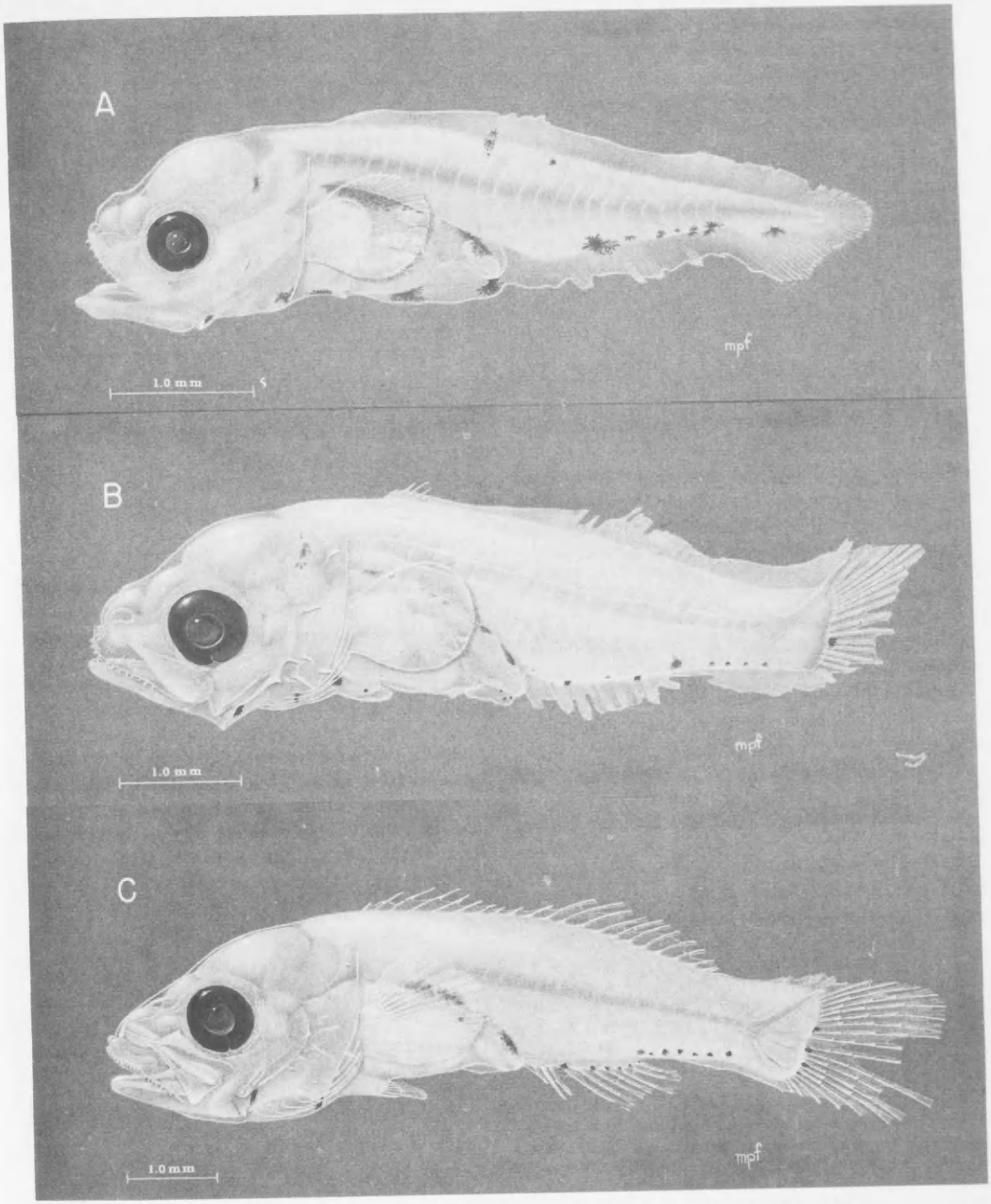

FIGURE 3.—Black sea bass larvae. A) 5.1 mm SL; B) 6.2 mm SL; C) 7.9 mm SL.

are large. The caudal fin outline varies from rounded to trilobed, with one upper ray produced in larger specimens.

Head Length

Between 2 and 4 mm head length averaged about 33% of SL. At 5 mm it reached 37-38% where it remained through 12 mm. Almost all values lie between 30 and 40%, except in a few larvae smaller than 5 mm where precise measurement is difficult. The juveniles demonstrate a continuing trend toward a longer head ranging from 34 to 45% of SL. Miller (1959) gives 40-41% as the proportion in his specimens (Figure 4A).

Eye Length

Eye length remained constant throughout larval development at about 9-10% of SL. Most juveniles as well as Miller's (1959) adult specimens also ranged from 9 to 10% (Figure 4B).

Snout Length

In larvae between 2 and 6 mm snout length increased from 6 to 11% of SL where it holds through adulthood (Miller, 1959) (Figure 4C).

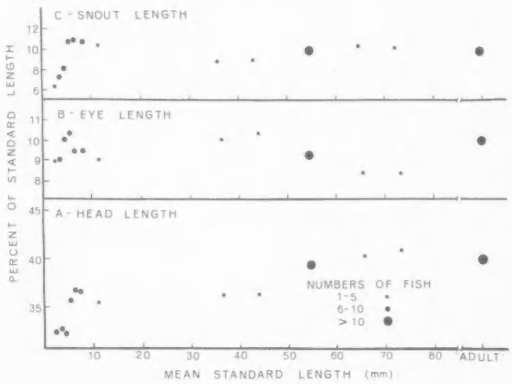

FIGURE 4.—Body proportions of black sea bass associated with the head plotted as percentages of standard length. A) head length; B) eye length; C) snout length. Each point represents the mean of several observations. "Adult" points from Miller (1959).

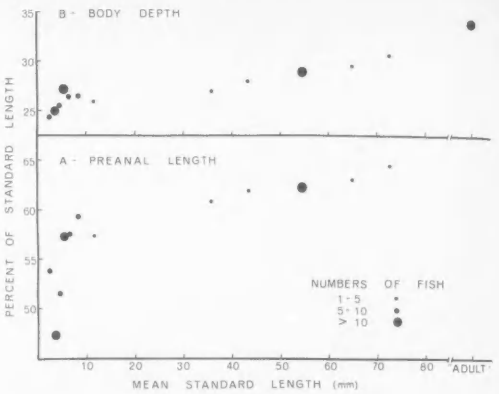

FIGURE 5.—Body proportions of black sea bass associated with the trunk plotted as percentages of standard length. A) preanal length; B) body depth. Each point represents the mean of several observations. "Adult" points from Miller (1959).

Preanal Length

The preanal length increases from about 50% of SL at 5 mm to 58% at 10 mm. During juvenile development it increases to nearly 65% (Figure 5A).

Body Depth

Relative to standard length, body depth increases from about 25 to 27% during larval development. During the juvenile stage it continues to increase to about 30% (Figure 5B). The adult proportion is about 34% (Miller, 1959).

Total Length

Total length is 102% of SL from 2 to 5 mm. As caudal fin development proceeds total length becomes a larger portion of standard length, reaching 120% in our largest larva. It remains constant through juvenile development at about 125% of SL (Figure 6A).

Caudal Peduncle Depth

From 4 mm where caudal peduncle depth is 6% of SL it increases steadily through larval

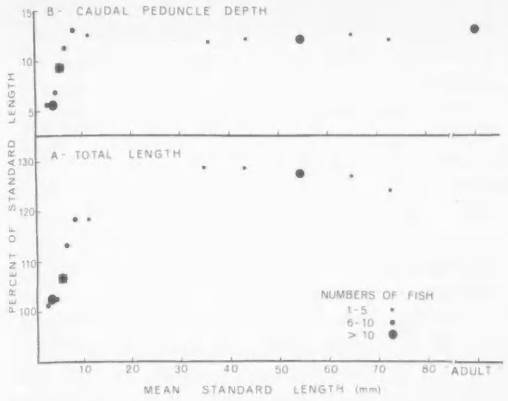

FIGURE 6.—Body proportions of black sea bass associated with caudal fin development plotted as percentages of standard length. A) total length; B) caudal peduncle depth. Each point represents the mean of several observations. "Adult" points from Miller (1959).

development to about 14% where it remains in adults (Miller, 1959) (Figure 6B).

DEVELOPMENT OF MERISTIC CHARACTERS

Most of the meristic features of black sea bass larvae develop within a length range of 4 mm (Table 1). Larvae 5 mm long have undifferentiated finfolds with a few caudal rays, buds of paired fins, some gill rakers and branchiostegal rays, and an incompletely ossified vertebral column (Figure 3A). By 7 mm most median and paired fin elements and branchiostegal rays have formed, some gill rakers are visible, and the vertebral column is ossified (Figure 3B). Other than gill rakers and scales, adult complements of meristic characters are reached by 9 mm (Figure 3C). The following descriptions roughly follow the sequence of attainment of adult characters.

TABLE 1.—Development of meristic characters of larval black sea bass.

SL (mm)	Caudal fin rays				Dorsal fin		Anal fin		Pectoral fin rays	Pectoral fin elements	Vertebrae	Branchiostegal rays	Gill rakers
	Sec.	Primary		Sec.									
	Upper	Upper	Lower	Lower	Spines	Rays	Spines	Rays					
3.2													
3.4													
4.0													
4.1													
4.5												2	
4.5												4	
4.6					1	1					3	7	5
4.8													
4.9											9	4	
5.0											10	4	8
5.0		6	5			1					12	5	6
5.2		6	6						2		14	5	5
5.3		8	6								15	5	5
5.5		6	7								15	5	6
5.5		5	4		5	6		5	3		11	5	5
5.9		6	4			5		5	7		18	3	6
5.9		7	5		7	6		7	5		20	6	8
6.0		8	7		8	8		8	9	3	22	6	8
6.1		5	4		6	9		7	7		22	5	8
6.3		8	7		2	10		8	9	3	16	6	9
6.5		9	7	2	9	8	2	8	12	5	23	7	8
6.6		9	8	1	8	18	2	8	14	4	23	6	8
6.7		9	8	1	14	11	2	8	16	4	24	7	11
6.7		9	8		8	11	2	8	12	4	23	6	7
7.0		9	8	2	9	10	3	7	10	5	24	7	10
7.1		9	8	2	10	10	3	7	14	5	24	7	10
7.7		9	8	3	10	11	3	7	13	6	24	7	11
8.7	4	9	8	4	10	11	3	7	18	6	24	7	10
9.9	4	9	8	3	10	11	3	7	19	6	24	7	11
10.6	9	9	8	8	10	11	3	7	18	6	24	7	14
11.0	9	9	8	8	10	11	3	7	18	6	24	7	16
11.8	5	9	8	5	10	11	3	7	18	6	24	7	15

[1] Damaged.

Teeth

At 5 mm, widely spaced small conical teeth are visible on the premaxillaries (Figure 3A). By 6.5 mm teeth are fairly closely spaced all along the premaxillaries and medially on the dentaries (Figure 3B). By 10 mm the teeth on the premaxillaries are very closely spaced and slightly recurved; those on the dentaries are enlarged and more widely spaced posteriorly but resemble those on the premaxillaries anteriorly.

Axial Skeleton

Ossification of the vertebral column proceeds posteriorly beginning between 4.5 and 5.0 mm. Neural and hemal spines form concurrently with their associated vertebrae. By 5 mm the anterior 12 vertebrae have ossified. By 6.5 mm all of the vertebrae are ossified except two or three anterior to the urostyle. The urostyle ossifies at 6 mm. The penultimate and antepenultimate vertebrae ossify last at 7 mm (Table 1). The first caudal supports to ossify are the medial four hypurals at 6.5 mm. Hypural 1 is ossified at 8.0 mm and hypural 6 is ossified at 8.5 mm. The uroneural and epurals form at 10 mm.

The structure of the caudal region at 11.8 mm (Figure 7) varies only slightly from the typical perciform type described by Gosline (1961). As in other serranids, the two separate uroneurals have fused, but no fusion of the hypurals has occurred. Otherwise the caudal skeleton is typical, having three epurals, a urostyle with a single ossification, and the hemal arch on the antepenultimate and penultimate vertebrae being autogenous (not fused to the vertebrae). There are 15 branched segmented rays supported by six hypurals, 7 ventrally on hypurals 1, 2, and 3 and 8 dorsally on hypurals 4, 5, and 6. One ray dorsal and one ray ventral to these are also segmented but not branched. About eight raylets form dorsally and an equal number form ventrally anterior to the segmented rays. If the first hypural is considered a parhypural (Nybelin, 1963), black sea bass have only two ventral hypurals.

Branchiostegal Rays

The first branchiostegal rays form at about 4.5 mm. By 5 mm four to six rays have formed and at 6.5 mm the adult complement of seven rays is reached, with the medial ones being the last to form (Table 1).

Caudal Fin

From 2 to 4 mm the finfold is symmetrical around the tip of the notochord. Actinotrichs are formed adjacent to the posterior 10% of the

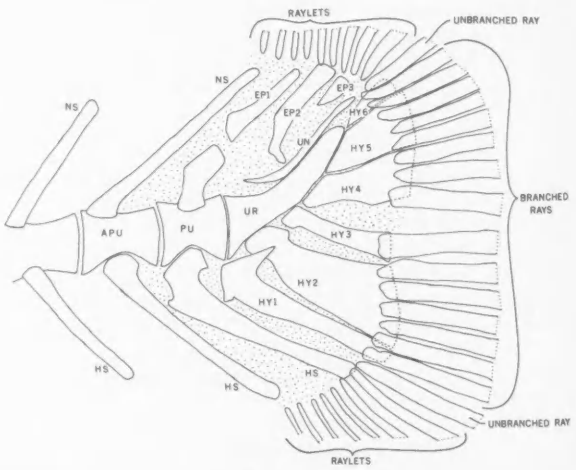

FIGURE 7.—Caudal skeleton of a black sea bass larva 11.8 mm SL. APU = antepenultimate vertebra; EP = epural; HS = hemal spine; HY = hypural; NS = neural spine; PU = penultimate vertebra; UN = uroneural; UR = urostyle.

notochord. Between 4 and 5 mm the anlage of the base of the caudal fin starts to form ventral to the notochord, just anterior to its tip (Figure 3A). By 5.5 mm the notochord is slightly upturned, the developing hypural region appears bilobed and about nine primary caudal rays are formed. The caudal fin at 6 mm has a rounded homocercal outline and eight segmented principal rays in the superior lobe and seven in the inferior lobe (Figure 3B); the rays are branched and some secondary procurrent rays are present. At 8 mm the dorsal hypurals are slightly longer than the ventral ones and the rays and raylets are more clearly defined and approaching the adult complement (Table 1).

Anal Fin

Between 2 and 5 mm there is an undifferentiated finfold in the area of the anal fin. Between 5 and 6 mm, fin rays start to form in the anal finfold between the vent and the most prominent pigment spot on the ventral surface of the trunk (Figure 3A). By 6 mm about six rays and one anal spine are seen (Figure 3B). The finfold posterior to the fin is reduced. By 7 mm the three anal spines are formed. The second spine is first to form and is most prominent throughout development (Figure 3C). The third spine forms as a ray; by 7 mm the spinous form is apparent. The first spine is smaller than the others and forms last at 6.5 mm. By 7 mm the adult complement of seven anal rays is reached and some are branched (Table 1).

Dorsal Fins

The undifferentiated dorsal finfold extends from the nape to the caudal region at 4 mm. By 5 mm the finfold becomes elevated about halfway back on the body where fin ray development begins (Figure 3A). Rays and spines develop along the dorsal fin base and the dorsal finfold posterior to the dorsal fin disappears between 5.5 and 6.5 mm. The anterior spines and posterior rays develop at a smaller size than intermediate fin elements.

The first four dorsal spines are visible by 6 mm. The second through fourth are longer and remain so. The first dorsal spine is about half as long as the second. The second and third spines are the same length at 6.5 but, by 10 mm, the third has become 1.5 times longer than the second. The fourth spine, the longest, is slightly longer than the third. The final complement of 10 spines and 11 rays is attained by 8.7 mm (Table 1). The rays are branched and segmented by 8 mm (Figure 3C).

Median Fin Supports

Anterior interneurals and the interhemal supporting the second anal spine ossify concurrently at about 8.5 mm. By 10 mm most of the interneurals and interhemals are formed. The anterior two interneurals fuse to support the first two dorsal spines (Figure 8). The first two anal spines are supported by one interhemal, apparently formed by fusion of two elements (Figure 8).

Pelvic Fins

Buds of the pelvic fins are seen on 4-mm larvae. Fin rays form between 4 and 6 mm. Rays and spines are first seen between 5 and 6 mm (Figure 3B). At 8 mm the adult complement of one spine and five rays has formed, with the smooth spine two-thirds as long as the longest ray (Table 1).

Pectoral Fins

Pectoral fin buds are present on the smallest larvae (2.1 mm) examined. The early pectorals change little until fin rays appear between 5 and 6 mm. By 6.5 mm the rays are mostly formed and the adult complement of 18 or 19 rays is reached by 9 mm (Table 1).

Gill Rakers

At 5 mm gill rakers appear as a few tubercles on the gill arches. By 6 mm there are nine rakers on the lower limb and none on the upper. At 10.6 mm there are 4 rakers on the upper and 10 on the lower limb. The adult complement of about 10 upper and 18 lower is reached in juveniles.

Scales

Scale formation occurs at a size between the largest larva (13.0 mm), which is scaleless, and the smallest juvenile (37 mm) in our collections.

PIGMENT PATTERNS

Pigmentation on Formalin-preserved black sea bass consists of a few melanophores in characteristic positions, mainly along the ventral part of the larva (Figure 9). Other kinds of larvae in the collections with spots in similar positions had meristic counts and body shapes approximating black sea bass. However, the relative size of the various spots in combination with examination of the sequence of development of meristic characters, the distinctive fin element counts on larger larvae, and body shape assured separation of black sea bass from other larvae.

Head Region

At 5 mm one spot usually forms ventrally on the median cartilage between the dentaries and urohyal. A second forms posterior to this on some specimens (Figure 9). A spot forms at 4 mm on each angular (Figure 3A). A characteristic transverse dentritic spot forms immediately anterior to the symphysis of the cleithra. Usually there is a spot between the bases of the pelvic fins. Dorsally there is a variable number of spots irregularly spaced on the posterodorsal covering of the cerebellum, and generally a pair of spots internally on the posterior surface of the midbrain. Between 12 and 13 mm a band of minute melanophores develops from the angular, past the eye, to the anterior part of the cerebellum. There are also several larger spots on the anterior halves of the cerebral hemispheres and a group of spots which originate at the eye and extend posteriorly to the opercular flap.

Gut Region

Considerable internal pigmentation develops in the dorsal area of the gut cavity, mostly on the surface of the viscera. These are large spots but superficially not readily definable. In larvae up to about 6 mm, this pigment reaches the exterior as a large intense spot on the posterior region of the renal tract (Figures 3A and B). In some specimens there is a smaller spot just anterior to the vent and another one about midway between the origin of the pelvic fins and the vent, along the midventral line (Figure 9).

Trunk and Caudal Region

Occasionally a few irregular spots occur dorsally on the trunk about midway on the body. Between 12 and 13 mm, a series of about six groups

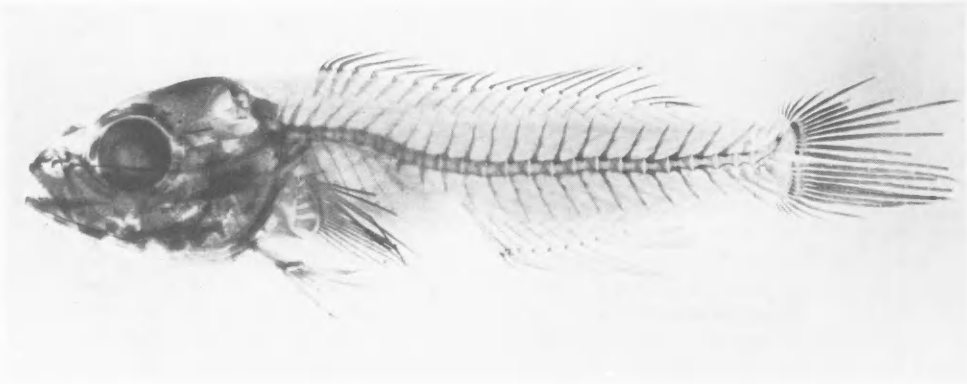

FIGURE 8.—Cleared and stained black sea bass larva 11.8 mm SL.

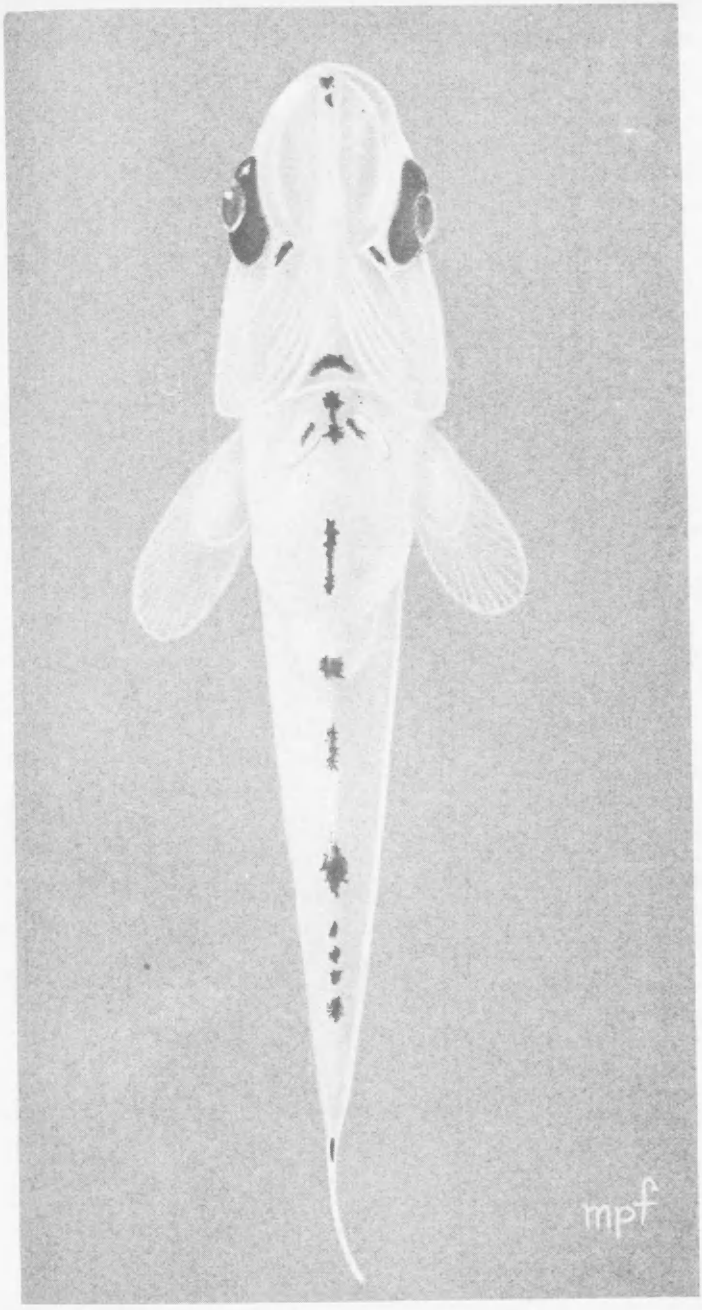

FIGURE 9.—Ventral view of pigment on a 5.4-mm black sea bass larva.

of small melanophores develops along the lateral line. At this length a few spots also develop at the origin of the dorsal fin. As the anal fin rays form, spots develop at some of their bases. A prominent spot forms early, near the posterior end of the anal fin; it is followed by four to six smaller spots along the midventral line that extends to the base of the caudal fin where there is another large spot. Before notochord flexion there is a prominent spot on the developing fin rays (Figure 9). This persists as the fin develops and reaches a position at the bases of some of the ventral rays of the caudal fin. As the caudal rays develop, some less prominent spots appear on rays dorsally and ventrally from the first spot. The pigment in the caudal region and along the midventral line persists through larval development.

LARVAL OCCURRENCES

Black sea bass larvae were taken on five cruises from June to November 1966, between Sandy Hook, N.J., and Cape Lookout, N.C. (Appendix Table). Of 39 tows containing black sea bass larvae, 20 had only one larva, and only two had more than 20 larvae; thus only limited inference about their distribution and relative abundance can be derived from these data. Larvae were taken in both shallow (0-15 m) and deep (18-33 m) tows from 4 to 82 km from shore. Water depths in the areas of capture ranged from 15 to 51 m. Surface temperature varied from 14.3° to 28.0°C; that on the bottom from 8.3° to 26.6°C. Surface salinity varied from 30.3 to 34.6‰.

Seasonally, there seems to be some northerly progression of spawning. During June one larva was taken off Oregon Inlet, N.C., and one off Paramore Island, Va. (Figure 10). During August, larvae occurred from Cape Henlopen, Del., to Ocracoke Inlet, N.C., being most abundant off Maryland and Virginia (Figure 11).

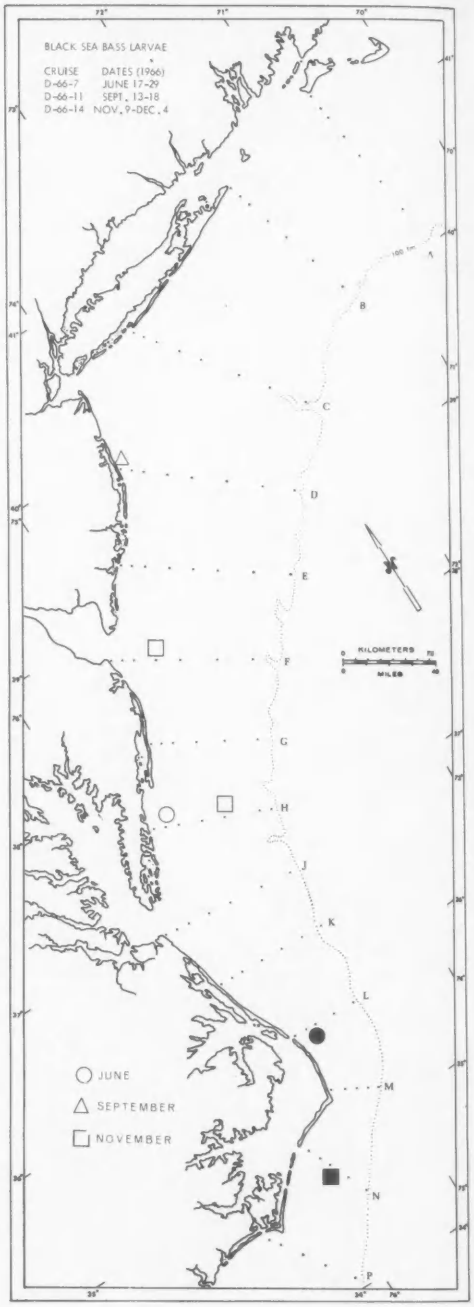

FIGURE 10.—Occurrence of black sea bass larvae in shallow (0-15 m) (open symbols) and deep (18-33 m) (solid symbols) tows. Three RV *Dolphin* cruises, 1966.

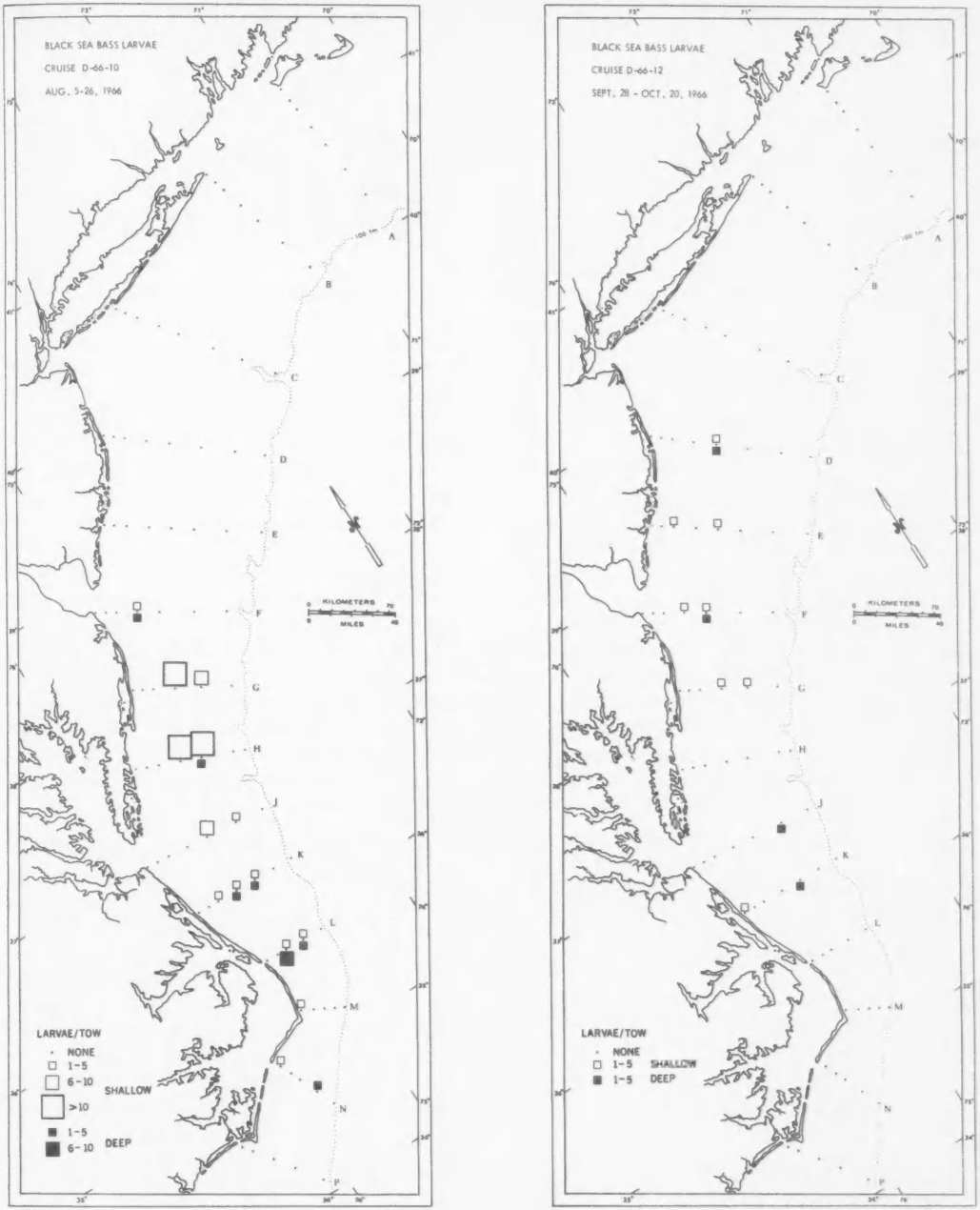

FIGURE 11.—Distribution and abundance of black sea bass larvae in August (left) and October (right) from RV *Dolphin* cruises.

During September only the four northern transects were sampled and the only larva taken was off Barnegat Inlet, N.J. (Figure 10). During October larvae ranged from Great Egg Inlet, N.J., to Currituck Light, N.C. In November four larvae occurred between Cape Henlopen, Del., and Ocracoke Inlet, N.C. (Figure 10).

The larvae ranged from 2.1 to 13.0 mm SL (Figure 12). Among the cruises the mean size of larvae was nearly constant. The length-frequency curve indicates that we undersampled small larvae (< 4 mm), probably because they were extruded through the meshes of the net. Comparisons of mean lengths of larvae taken during day and night and in shallow and deep tows for the individual cruises were made. Larvae in the deep net were slightly larger than those in the shallow net. Day-night differences in size were inconclusive (Table 2). Geographic variations in size are not apparent.

A comparison of fish caught per successful tow in shallow and deep tows taken during day and night shows that more fish were taken in shallow than in deep tows and more were taken at night than during day (Table 2). Our data on size and diurnal and depth distribution of the larvae indicate several things. More and slightly larger larvae were taken at night than during the day. Also, larvae in the deep net were slightly larger than those in the shallow net. More larvae were taken in the shallow than in the deep net. Thus it appears that larvae are more abundant near the surface (0-15 m) than deeper (18-33 m) waters and that visual warning allows larger larvae to escape in near surface waters, particularly during the day.

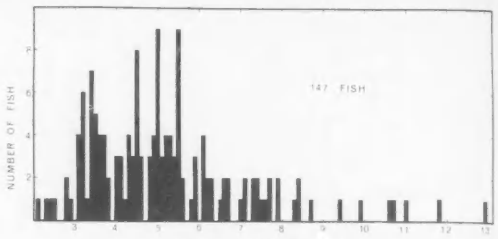

FIGURE 12.—Length distribution of black sea bass larvae from RV *Dolphin* cruises, 1966.

DISCUSSION

The general distribution of larvae and juveniles of black sea bass can be deduced from their occurrence in several disjunct studies of estuaries and coastal waters of the Atlantic coast. Early larvae (< 6 mm) have been found at the mouth of Chesapeake Bay (Pearson, 1941), in Long Island Sound (Perlmutter, 1939), and in Narragansett Bay (Herman, 1963). The lack of black sea bass larvae in some intensive sur-

TABLE 2.—Black sea bass larvae from 1966 RV *Dolphin* cruises. Total numbers, numbers per positive tow, and lengths in shallow and deep tows by cruise and time of day.

Cruise	Time of day	Shallow				Deep			
				Length (mm)				Length (mm)	
		No.	No./tow	Range	Mean	No.	No./tow	Range	Mean
June	Day	1	1.0	4.6	4.6				
	Night					2	2.0	5.5- 5.9	5.7
Aug.	Day	32	6.4	2.1- 5.5	3.7	2	1.0	5.4- 7.9	6.7
	Night	72	9.0	2.8-10.7	5.4	16	3.2	2.5-11.8	6.3
Sept.	Day	1	1.0	5.4	5.4				
	Night								
Oct.	Day	7	1.8	4.3- 6.3	5.5				
	Night	6	1.5	3.5- 6.1	5.1	4	1.0	3.6- 7.3	5.5
Nov.	Day	1	1.0	7.5	7.5	2	2.0	7.6-13.0	10.3
	Night	1	1.0	5.2	5.2				
Day total or mean		42	3.5	2.1- 7.5	4.2	4	1.3	5.4-13.0	6.8
Night total or mean		79	6.1	2.8-10.7	5.4	22	2.2	2.5-11.8	6.1
Grand total or mean		121	4.8	2.1-10.7	5.0	26	2.0	2.5-13.0	6.5

veys along the Atlantic coast is remarkable (e.g., Merriman and Sclar, 1952; Wheatland, 1956; Richards, 1959; Massmann, Joseph, and Norcross, 1962; Marak et al., 1962). Ichthyoplankton sampling in more enclosed areas, such as Indian River, Del. (Pacheco and Grant, 1965) and Sandy Hook Bay, N.J. (Croker, 1965), has failed to reveal larvae. Juveniles (25-75 mm) have been taken from saline areas of estuaries from Florida (Tagatz, 1968), Maryland (Schwartz, 1961, 1964), Delaware (de Sylva, Kalber, and Shuster, 1962), New York (Perlmutter, 1939; Greeley, 1939; Richards, 1963), Rhode Island (Herman, 1963), and Massachusetts (Lux and Nichy, 1971). Bean (1888) reported that young about 1 inch (25 mm) long were common in Great Egg Harbor Bay, N.J., and Nichols and Breder (1927) reported 20-mm fish over oyster beds off Staten Island, N.Y., in August. Massmann et al. (1962) found one 43-mm juvenile in the ocean off Virginia.

Black sea bass spawn offshore along the coast from Florida to New England. Spawning takes place earlier in the southern part of the range than in the northern part; in May off North Carolina (Smith, 1907); in late May off Chesapeake Bay (Hildebrand and Schroeder, 1928); and into early summer off southern New England (Bigelow and Schroeder, 1953). At least some of the young, less than 30 mm, enter open estuaries near inlets where they spend their first summer associated with hard bottoms such as oyster shells (Nichols and Breder, 1927; Arve, 1960; Richards, 1963). Young leave the estuaries during fall and return during spring. Enough return to estuaries in subsequent years to support fisheries there. From references made to black sea bass abundance around the turn of the century (Bean, 1888; Smith, 1898; Sherwood and Edwards, 1901), it seems that present stocks in the northern part of the range are diminished. This decrease in abundance may be associated with decrease in oyster beds (Arve, 1960). Commercial catch records show recent catches near the historical mean, but indicate a shift in abundance from the New York-Delaware to the Chesapeake region (Lyles, 1967).

Our data on offshore occurrences of larvae complement work in estuaries where early stages have been found. However, a definitive picture of the early life history of this species is still lacking. The small numbers of larvae taken in this survey do not seem consistent with the population size and extent of adult black sea bass along the coast. Possibly we sampled in a year when spawning was unsuccessful or our sampling was not effective for capturing black sea bass larvae in proportion to their abundance.

The pelagic existence of this fish is short. Larvae longer than 13 mm were not taken, presumably because near that size they assume demersal or estuarine habits. Few of these late larvae and early juveniles have been collected, and it is still not known what part of the population may enter estuarine waters and what part remains at sea. The routes and mechanisms of larval transport from spawning grounds to nursery areas are also unknown.

The known seasonal distribution of larvae shows that black sea bass spawn over a long period. The range of juvenile sizes taken in individual samples also indicates a long spawning season. Details of the suggested northward progression of spawning need clarification. Intensive sampling of the water column and bottom offshore, at inlets, and in open estuaries could resolve these deficiencies in our knowledge of black sea bass life history.

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APPENDIX TABLE.—RV *Dolphin* 1965-66 ichthyoplankton survey, Data associated with Gulf V catches of black sea bass larvae.

Cruise station	Tow depth (m)	Larvae			Date (1966)		Tow start time (EST)	Light condition[1]	Water depth (m)	Temperature (°C)				Thermocline		Salinity (‰)	
		Number	Lengths (mm SL)							Range	Mean	Surface	Bottom	Degree	Depth (m)	Range	Mean
			Mean	Range	D	M											
D-66-7																	
H 2	0- 6	1	4.6		27	6	1521	Day	22	18.1-21.2	19.6	21.2	15.5	Weak	2-11	30.3-31.0	30.7
L 3	18-24	2	5.7	5.5- 5.9	22	6	2144	Night	38	15.3-15.4	15.3	16.7	15.6	None	--	32.8-32.8	32.8
D-66-10																	
F 5	0-15	3	3.6	2.8- 4.5	9	8	2352	Night	34	14.8-22.4	20.7	22.4	8.6	Strong	9-19	30.9-30.9	30.9
F 5	18-24	1	3.7		9	8	2352	Night	34	8.8-11.5	9.5	22.4	8.6	Strong	9-19	31.1-31.3	31.2
G 4	0-15	17	3.6	2.3- 5.1	21	8	0930	Day	28	15.8-23.6	21.9	23.6	9.7	Strong	8-18	30.7-31.0	30.9
G 5	0-15	7	4.0	3.1- 5.5	21	8	1255	Day	49	16.3-24.2	21.2	24.2	5.8	Strong	3-23	30.1-30.8	30.4
H 4	0-15	24	5.9	3.2-10.6	22	8	0305	Night	26	12.6-24.5	21.6	24.5	9.8	Strong	10-17	30.5-31.1	30.6
H 5	0-15	28	4.9	3.2- 7.3	22	8	0139	Night	40	18.8-25.4	23.7	25.4	8.4	Strong	11-22	30.5-31.0	30.7
H 5	18-24	3	5.3	4.8- 6.1	22	8	0139	Night	40	9.7-14.8	11.7	25.4	8.4	Strong	11-22	31.0-31.2	31.1
J 5	0-15	8	6.5	4.2-10.7	22	8	2347	Night	26	15.7-26.1	21.2	26.1	10.3	None	--	30.4-31.2	30.7
J 6	0-15	1	9.4		23	8	0335	Night	35	18.5-25.8	23.6	25.7	8.3	Strong	6-24	30.3-30.6	30.5
K 3	0-15	2	4.6	3.2- 6.1	24	8	1954	Night	25	15.0-24.4	22.1	24.4	14.8	Strong	7-15	30.7-31.1	30.8
K 4	0-15	21			23	8	1857	Night	27	14.5-25.5	22.0	25.5	10.5	Strong	8-18	30.3-31.3	30.9
K 4	18-24	2	11.4	11.0-11.8	23	8	1857	Night	27	10.8-12.9	11.7	25.5	10.5	Strong	8-18	30.8-31.6	31.3
K 5	0-15	2	5.0	5.0- 5.0	23	8	1718	Day	30	19.4-26.4	22.9	26.4	9.6	Strong	7-23	31.2-31.3	31.3
K 5	18-24	1	5.4		23	8	1718	Day	30	10.2-15.4	12.3	26.4	9.6	Strong	7-23	31.4-31.7	31.6
L 3	0-15	5	4.5	3.2- 6.3	25	8	0445	Night	33	16.9-24.6	22.2	24.6	16.4	Strong	7-14	31.3-31.9	31.5
L 3	18-24	8	6.6	3.6- 8.4	25	8	0445	Night	33	14.7-16.4	15.6	24.6	16.4	Strong	7-14	32.2-32.7	32.5
L 4	0-15	5	3.2	2.1- 4.3	25	8	0618	Day	41	24.9-25.8	25.6	25.8	16.0	Strong	19-25	31.9-33.6	32.4
L 4	18-33	1	7.9	7.9- 7.9	25	8	0618	Day	41	15.6-24.1	18.1	25.8	16.0	Strong	19-25	31.2-34.5	33.3
M 1	0- 6	1	3.3		25	8	1212	Day	15	25.4-25.4	25.4	25.4	25.4	None	--	31.4-31.6	31.5
N 1	0-15	1	4.5		25	8	2036	Night	22	27.1-27.2	27.2	27.2	26.6	None	--	34.6-34.8	34.7
N 4	18-33	2	2.7	2.5- 2.9	26	8	0009	Night	48	22.9-27.5	25.2	28.0	21.6	Weak	17-41	34.8-35.3	35.0
D-66-11																	
D 1	0- 6	1	5.4		18	9	1413	Day	16	21.0-21.1	21.0	21.1	20.7	None	--	30.4-30.5	30.5
D-66-12																	
D 5	0-15	1	5.0		12	10	2204	Night	36	16.5-16.6	16.6	16.6	11.0	Weak	23-37	31.2-31.3	31.2
D 5	18-24	1	7.1		12	10	2204	Night	36	15.5-16.4	16.1	16.6	11.0	Weak	23-37	31.2-31.4	31.3
E 3	0- 6	1	5.0		5	10	1323	Day	22	17.4-17.4	17.4	17.4	16.9	None	--	30.8-30.9	30.8
E 5	0-15	11	6.1		11	10	2210	Night	35	16.4-16.6	16.5	16.6	9.0	Strong	22-31	31.2-31.4	31.3
F 4	0-15	2	4.2	3.5- 5.0	5	10	0227	Night	22	17.7-18.0	17.8	18.0	17.7	None	--	30.8-30.9	30.8
F 5	0-15	2	5.4	5.3- 5.6	4	10	2151	Night	35	17.4-17.9	17.7	17.9	14.2	Weak	18-24	30.7-30.9	30.8
F 5	18-24	1	3.6		4	10	2151	Night	35	14.9-17.0	16.1	17.9	14.2	Weak	18-24	30.9-30.9	30.9
G 4	0-15	1	6.3		4	10	0627	Day	31	18.1-18.2	18.2	18.2	15.8	None	--	31.0-31.1	31.0
G 5	0-15	4	5.8	5.5- 6.1	4	10	0816	Day	51	17.4-18.0	17.8	18.0	9.4	Strong	19-26	30.9-31.0	30.9
J 6	18-24	1	4.1		2	10	2125	Night	35	14.9-18.0	16.6	19.5	10.1	Weak	16-28	31.5-31.6	31.5
K 1	0-15	1	4.3		1	10	0730	Day	17	19.7-21.4	20.8	21.4	19.7	None	--	30.4-30.9	30.6
K 5	18-24	1	7.3		1	10	0010	Night	33	12.9-15.9	13.9	21.6	12.3	Weak	11-22	30.8-31.0	30.9
D-66-14																	
F 4	0-15	1	5.2		11	11	0312	Night	22	14.2-14.3	14.2	14.3	14.2	None	--	32.8-33.0	32.9
H 5	0-15	1	7.5		12	11	0754	Day	42	14.4-15.3	14.8	15.3	14.0	None	--	33.3-33.5	33.5
N 3	18-24	2	10.3	7.6-13.0	16	11	0833	Day	30	19.4-19.5	19.4	19.3	19.4	None	--	35.8-35.9	35.9

[1] Day tow: start time between sunrise and 0.5 hr before sunset; night tow: start time between sunset and 0.5 hr before sunrise.
[2] Larva too mutilated for accurate measurement.

UREA AND OTHER NITROGENOUS NUTRIENTS IN LA JOLLA BAY DURING FEBRUARY, MARCH, AND APRIL 1970

JAMES J. MCCARTHY[1] AND DANIEL KAMYKOWSKI[2]

ABSTRACT

Samples collected from La Jolla Bay twice weekly for 2½ months were analyzed for nitrate, nitrite, ammonium, and urea in addition to other chemical, physical, and biological parameters. On the basis of an infestation of blue sharks (*Prionace glauca*), periods before, during, and after the infestation were defined. Statistical analyses indicated that: 1) Urea concentrations were highest during the period of shark infestation. 2) There was strong positive correlation between phaeo-pigment/chlorophyll ratios and ammonium concentrations during the infestation but none between the pigment ratios and either the ammonium concentrations for the other two periods or the urea concentrations for any of the three periods. 3) There was no correlation between ammonium and urea concentrations before, a strong positive correlation during, and no correlation after the shark infestation. 4) Urea was the only nitrogenous nutrient for which the concentrations above and below the thermocline were not different. 5) Comparisons between two stations 1.5 km distant indicate that on a horizontal scale, the patch structure for urea is smaller than that of the other nitrogenous nutrients although the median urea concentration in the water column was not different at the two stations.

The temporal similarity and the more complex patch structure for urea (as seen in 4 and 5 above) suggest that the blue sharks were responsible for the higher urea concentrations during the infestation. Although the median ammonium concentrations before and during the infestation were not different, the strong positive correlation between ammonium and urea concentrations during the infestation hint that the sources or rates of supply and utilization for both nutrients may have been closely related. The strong positive correlation between phaeo-pigment/chlorophyll ratios and ammonium concentrations during the infestation may imply that the source of ammonium was herbivore excretion.

The nitrogenous plant nutrients in the marine environment classically include the nitrate, nitrite, and ammonium ions. The fixation of dissolved gaseous nitrogen has been observed in both the Sargasso Sea and Arabian Sea (Dugdale, Goering, and Ryther, 1964) and may for certain areas be a significant process (Dugdale and Goering, 1967). More recently, evidence has been presented which suggests that both urea (McCarthy, 1971) and certain amino acids (North and Stephens, 1971) may also be of importance as nitrogenous nutrients. The purpose of the present study was to compare the pattern of distribution for urea with those for ammonium, nitrite, nitrate, and other chemical, physical, and biological parameters in the La Jolla coastal waters.

In contrast to the other nitrogenous nutrients, little is known about the distribution, the importance, or the cycle of either urea or amino acids in marine waters. The results of quantitative analyses for urea in a total of approximately 120 samples of seawater have been reported by Newell (1967) and McCarthy (1970). Newell's samples were collected from a depth of 10 m at 25 stations in the English Channel and 45 of

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McCarthy's were collected from 9 profiles (5 samples each) in the euphotic zone of the Peru Current. One of the obvious features of both sets of data is the high degree of variability between samples, even those only a few meters vertically distant from one another. There was no consistent pattern in the profile data although higher values tended to occur at intermediate depths in the euphotic zone. It has been shown that urea accounts for a significant fraction of phytoplankton nitrogen uptake off the coast of southern California (McCarthy, in press), and it has been suggested that animal excretion is the major source of urea in the euphotic zone of that area (McCarthy and Whitledge, 1972).

Ammonium concentrations are usually low in coastal waters, but this ion can, at times, be the most abundant form of nitrogen available for phytoplankton utilization. It is the major nitrogenous excretory product of most marine animals (Parry, 1960; Baldwin, 1964) and as such is recycled rapidly in surface waters. The importance of ammonium in phytoplankton nutrition has been demonstrated in the eastern tropical Pacific by Thomas (1966) and Thomas and Owen (1971).

Nitrite in neritic waters often shows marked differences with depth, and the concentration is usually somewhat less than that of ammonium (Vaccaro, 1965). Nitrite can be formed by bacteria through either the oxidation of ammonium or the reduction of nitrate. Phytoplankton can utilize nitrite as a source of nitrogen and have been shown to excrete extracellular nitrite when growing on high levels of nitrate (Vaccaro and Ryther, 1960; Carlucci, Hartwig, and Bowes, 1970).

In temperate coastal areas the distribution of nitrate in seawater usually shows a predictable seasonal pattern which is well documented (see Vaccaro, 1965). During the winter, vertical mixing and low rates of plant assimilation keep the nitrate concentration plentiful in near surface waters and rather uniform in vertical distribution. With the onset of spring, density stratification substantially reduces the vertical transfer of nitrate, and it is removed from the wind mixed surface waters via phytoplankton assimilation. Bacteria are probably responsible for regenerating nitrate through the oxidation of ammonium and nitrite (Harvey, 1966).

SAMPLE COLLECTION AND ANALYSIS

Samples were collected with PVC Van Dorn bottles off the coast of La Jolla, Calif., twice weekly from 7 February to 17 April 1970, at three stations in 50 m of water. Station II (Figure 1) was approximately 1 km directly seaward of Scripps Institution of Oceanography pier on the southern edge of Scripps Canyon, Station I was approximately 1.5 km SW of Station II on the southern edge of La Jolla Canyon, and Station III was approximately 1.5 km NW of Station II over the more gently sloping bottom north of both canyons. Water for the analysis of chemical and biological parameters was collected from the surface, 10, 20, 30, and 40 m depths at all three stations on each sampling day. Nutrient analyses were run on samples collected at Station II and alternately on those collected at Stations I and III (with a few exceptions). A Secchi disk reading and bathythermograph cast were always taken at Station II.

Immediately after sample collection, aliquots were drawn for oxygen determinations. They were "pickled" by the addition of the manganous sulphate and alkaline iodine solutions and were returned to the laboratory for the completion of the analysis. Within 2 hr after sample collection, aliquots were analyzed in duplicate for ammonium and urea while others were analyzed for chlorophyll *a* and phaeophytin *a*. Other aliquots were: 1) frozen and later analyzed (within 2 weeks) for nitrate, nitrite, silicate, and phosphate; 2) preserved for microscopic determination of phytoplankton species and numbers; and 3) stored (approximately 3 weeks) for salinity determinations.

The determinations of dissolved oxygen by a modified Winkler technique (Carritt and Carpenter, 1966), chlorophyll *a* and phaeophytin *a* by fluorometry (Holm-Hansen et al., 1965), nitrate by the cadmium-copper reduction and subsequent determination of nitrite (Wood, Armstrong, and Richards, 1967), nitrite by diazotization (Bendschneider and Robinson, 1952),

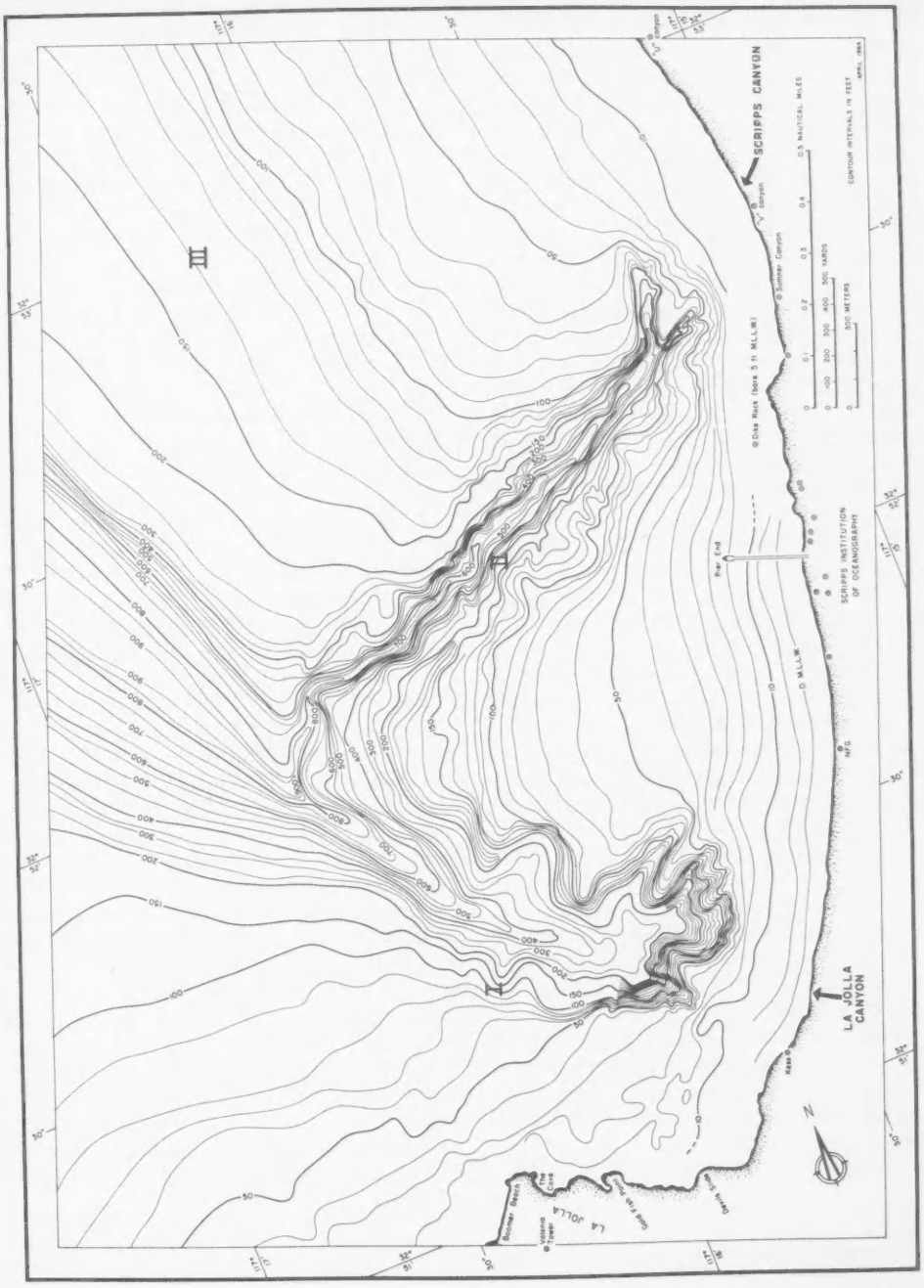

FIGURE 1.—The locations of Stations I, II, and III.

silicate by molybdate complexing (Mullin and Riley, 1955), and phosphate by molybdate complexing (Murphy and Riley, 1962) followed the procedures outlined by Strickland and Parsons (1968). Salinity was determined by conductivity measurements on an Autolab[R] salinometer.[3]

Ammonium was determined by the phenolhyochlorite method (Solórzano, 1969) and urea by the urease method (McCarthy, 1970), but both of these methods deserve additional comment. Solórzano states that for ammonium analyses the absorbance of samples is stable for at least 24 hr when a 0.5% sodium nitroprusside reagent is used, whereas, at higher concentrations a high and unstable blank which increases with time can result. Difficulties such as those expected at higher sodium nitroprusside concentrations were, however, occasionally experienced when using the recommended concentration. Efforts made to determine the source of this problem were complicated by its erratic occurrence, e.g., differences from day to day using the same reagents. No solution to the problem was found. It is, however, of little consequence when absorbances are read within a short interval of time, e.g., 15 min, since the optical density increased uniformly in blanks, samples, and standards. When analyzing as many as 50 samples at once, the reagent additions were staggered in time so that the absorbance of a sample was always read between 1.00 and 1.25 hr later.

A problem was encountered with the Worthington URC crude urease which was recommended for the urease method. Several batches of this product were purchased over a period of a year, and following the outlined purification procedure, the preparations were almost identical in activity and blank. Shortly after the urease-urea method was published (McCarthy, 1970), two batches of the same product were received which yielded both less activity and higher blanks than the preceding preparations. Owing to these difficulties, Sigma Type III urease was used subsequently. The resultant blank is higher (0.030-0.050 OD units/10-cm cell) than previously described and approximately 3 mg rather than 0.5 mg of the enzyme preparation must be added to each sample. A 0.1-0.2 ml Biopipette[R] was found to be accurate and rapid enough to permit direct addition of the concentrated enzyme preparation without dilution. In addition, it was found that by centrifuging the final urease preparation approximately 1,000 $\times$ g for 20 min and discarding the pellet, turbidity of the preparation could be reduced. For laboratory analyses of urea McCarthy (1970) recommended the use of aluminum foil coverings for the reaction vessels, but it should be noted that if the sample contacts the foil an erroneously high ammonium value will result. If foil coverings are used, care should be taken when moving the flasks, and they should be discarded after the addition of the oxidizing solution. After the addition of the last reagent, color will not result from ammonium added to the sample whereas contact with the aluminum foil will still interfere with the results.

The nutrient data were shown to depart from normality in distribution by plotting them on normal probability paper, so parametric statistics could not be applied. The Mann-Whitney U test (Tate and Clelland, 1957) was used for comparing medians from different stations or different periods. This test compares the central tendency of two distributions and does not assume similarity in variance. The Tukey-Siegel modification of the Mann-Whitney U test was used to compare variability between sets of data, the median regression procedure (Tate and Clelland, 1957) was used to calculate the regression lines, and the *tau* coefficient test (Kendall, 1955) was used to determine correlations. The α for significant differences was taken at the 0.05 level except when there was multiple testing, in which cases $0.05/n$ was used where n = the number of times a test was run with interrelated data.

The data for dissolved oxygen, chlorophyll *a*, phaeophytin *a*, silicate, phosphate, phytoplankton species and numbers, temperature, and salinity will be reported elsewhere (Kamykowski).[4]

[3] Reference to trade names in the publication does not imply endorsement of commercial products by the National Marine Fisheries Service.

[4] Kamykowski, D. Some physical and chemical aspects of the phytoplankton ecology off La Jolla, California. Manuscript in preparation.

RESULTS

Representative plots of the nutrient data are shown in Figures 2 and 3. The nitrate concentrations consistently increased with depth. When a thermocline was present, the median nitrate concentration above was 0.49 μg at. N/liter while that below was 12.81 μ at. N/liter. The median nitrite concentration above the thermocline was 0.04 μg at. N/liter while that below was 0.36 μg at. N/liter. The median ammonium concentration above the thermocline was 0.09 μg at. N/liter while that below was 0.34 μg at. N/liter. Both the medians and the variabilities for nitrate, nitrite, and ammonium concentrations above the thermocline were significantly different from those below. The median urea concentration above the thermocline was 0.16 μg at. N/liter while that below was 0.12 μg at. N/liter, and neither the medians nor the variabilities were significantly different.

Urea data for stations made on the same day are plotted in Figure 4. We first noticed that the urea values appeared to vary markedly from one month to another, and since elasmobranches excrete nitrogen primarily as urea (Baldwin, 1964), this pattern suggested that the quantity of urea in the water may have been affected by a heavy infestation of 1-2 m long blue sharks (*Prionace glauca*). The infestation was first noted on 28 February, and initially one could see a few tens of dorsal fins extending above the surface at any time in the vicinity of any of the stations. After a few days the sharks became much more wary of the skiff and although they remained in great numbers, they were usually deeper. Shark sightings continued to be numerous until 21 March and thereafter they were rare. The periods before (7-24 February), during (28 February-21 March), and after (24 March-17 April) the infestation, hereafter referred to as Periods A, B, and C, are indicated in Figure 4. These periods define an initial stage of low urea values, a secondary stage of higher and more variable urea values, and a final stage which appears similar to the first. Medians and ranges for nitrate, nitrite, ammonium, and urea for the three periods are given in Table 1 and were used for the statistical analyses reported in Tables 2, 3, and 4. The highest concentration of urea detected at any time during the sampling program, 1.28 μg at. N/liter, was in a surface sample collected approximately 1 m from a 2½-m blue shark which was near Station I.

Comparisons between Periods A, B, and C Table 4) show that the periods differed with respect to nitrate, nitrite, and ammonium as well as urea. The median nitrate concentration in Period B was significantly lower than those in either Period A or Period C. The median nitrite concentrations were similar for all three periods. The median ammonium concentration for Period C was significantly lower than that for Period A. The median urea concentration for Period B was significantly higher than those for either Period A or Period C. Both the variability and the range of urea concentrations were considerably higher in Period B than in either Period A or Period C.

TABLE 1.—Medians, ranges, and number of samples for nitrate, nitrite, ammonium, and urea within each period. The medians and ranges for each form of nitrogen are in units of μg at. N/liter.

	Nitrate			Nitrite			Ammonium			Urea		
	Median	Range	Number	Median	Range	Number	Median	Range	Number	Median	Range	Number
Period A												
Stations I and III	6.91	0.50-19.07	20	0.25	0.04-0.36	20	0.29	0.00-0.71	20	0.09	0.00-0.18	20
Station II	6.87	0.53-19.00	20	0.21	0.05-0.44	20	0.27	0.00-0.73	20	0.03	0.00-0.25	20
All values	6.58	0.50-19.07	40	0.24	0.04-0.44	40	0.28	0.00-0.73	40	0.07	0.00-0.25	40
Period B												
Stations I and III	0.88	0.00-15.11	30	0.12	0.00-0.61	30	0.21	0.00-1.96	30	0.22	0.00-0.67	30
Station II	1.81	0.00-15.00	30	0.14	0.00-0.58	30	0.25	0.00-1.66	30	0.28	0.00-0.90	30
All values	0.88	0.00-15.11	60	0.13	0.00-0.61	60	0.23	0.00-1.96	60	0.27	0.00-0.90	60
Period C												
Stations I and III	9.43	0.09-23.16	35	0.20	0.00-0.88	35	0.06	0.00-0.59	35	0.09	0.00-0.24	35
Station II	10.09	0.00-20.87	35	0.25	0.00-0.73	35	0.09	0.00-2.38	35	0.12	0.00-0.56	35
All values	9.64	0.00-23.16	70	0.22	0.00-0.88	70	0.08	0.00-2.38	70	0.12	0.00-0.56	70

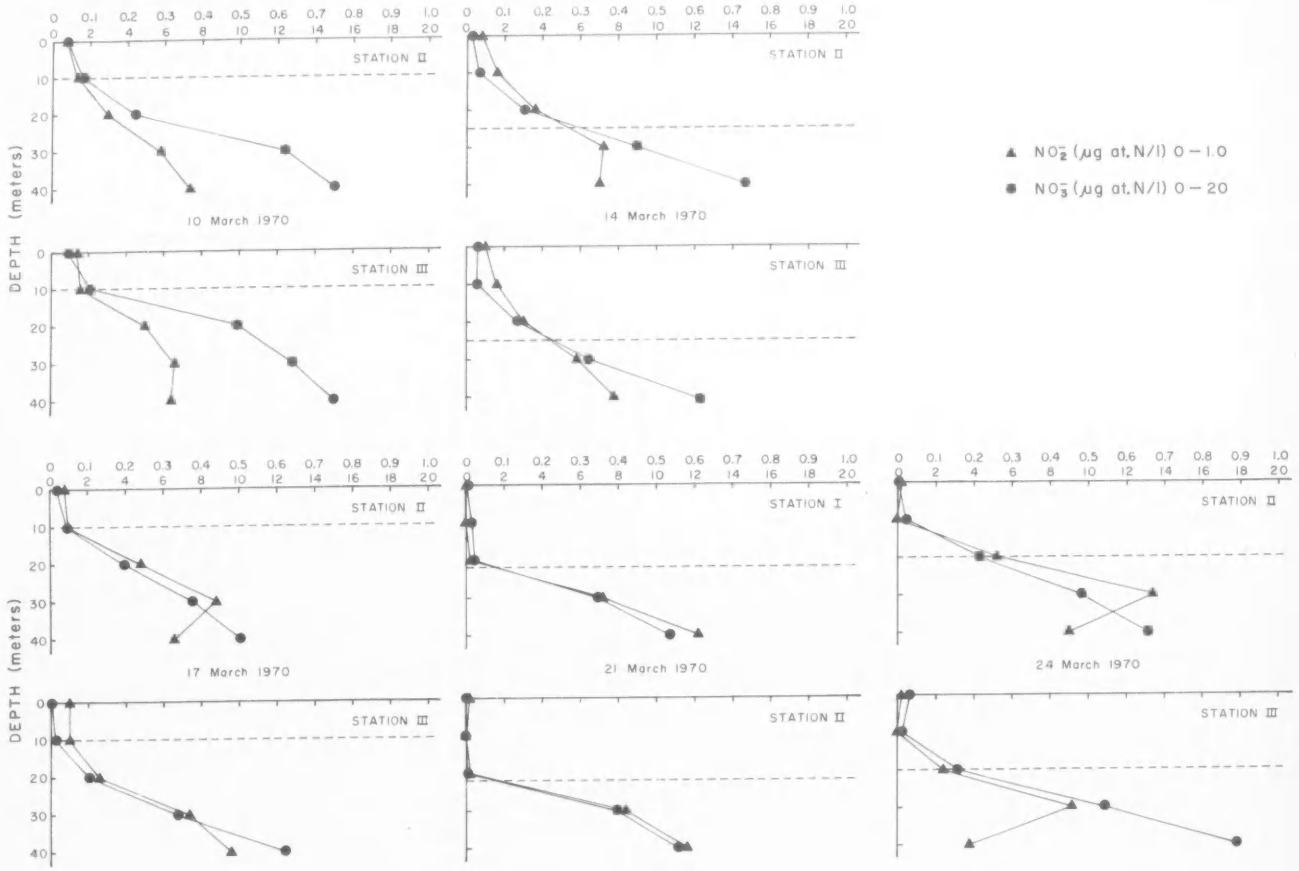

FIGURE 2.—Nitrate and nitrite concentrations for paired stations on five successive sampling days. The depth of the thermocline is indicated by the dashed line.

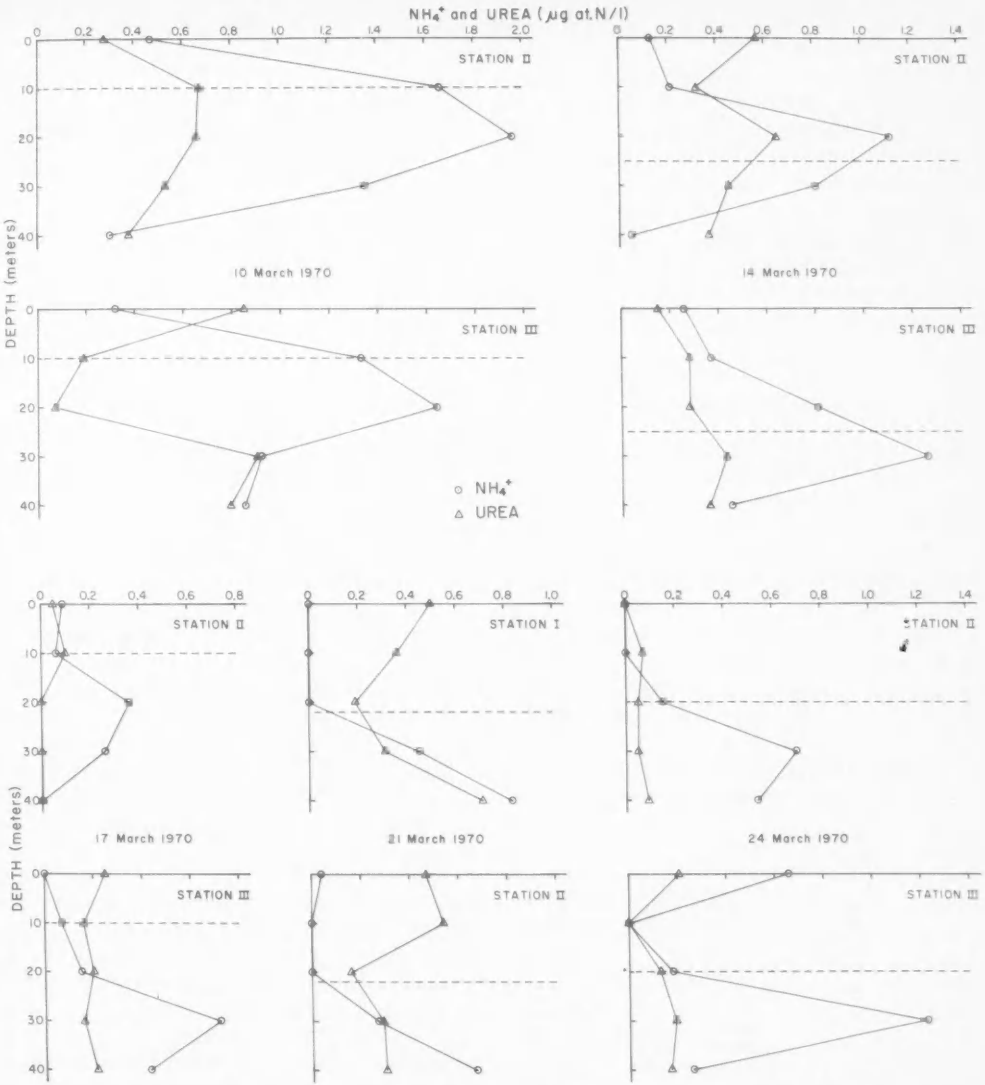

FIGURE 3.—Ammonium and urea concentrations for paired stations on five successive sampling days. The depth of the thermocline is indicated by the dashed line.

The *tau* coefficient was used to examine ammonium and urea concentrations for correlation in each of the three periods. From the z approximation the following pattern emerged: for Period A there was no correlation ($P = 0.030$), for Period B the correlation was positive ($P = 0.009$), and for Period C there was no correlation ($P = 0.124$). Values for the probabilities

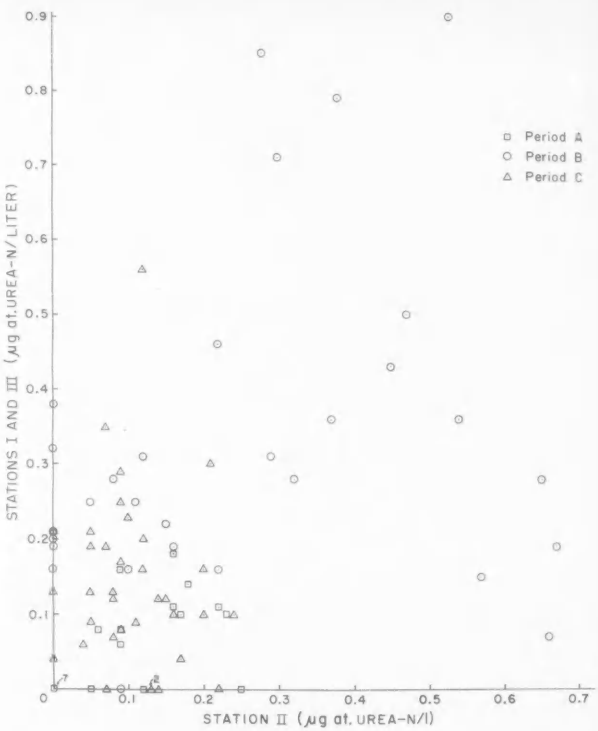

FIGURE 4.—Urea concentrations at the same depth for paired stations sampled on the same day during Period A, Period B, and Period C.

TABLE 2.—Linear regressions of Station I or III vs. Station II for nitrate, nitrite, ammonium, and urea within each period.

Nutrient	Period	Station I or III vs. Station II	P[1]
Nitrate	A	$Y = 1.00X + 0.50$	<0.05
	B	$Y = 0.99X - 0.05$	<0.05
	C	$Y = 0.97X + 1.00$	<0.05
Nitrite	A	$Y = 0.98X + 0.02$	<0.05
	B	$Y = 0.92X + 0.00$	<0.05
	C	$Y = 0.90X + 0.03$	<0.05
Ammonium	A	$Y = 1.10X - 0.02$	<0.05
	B	$Y = 1.76X + 0.17$	<0.05
	C	$Y = 1.42X + 0.02$	<0.05
Urea	A	$Y = 0.65X - 0.02$	<0.05
	B	$Y = 0.52X + 0.16$	>0.05
	C	$Y = 2.00X - 0.06$	>0.20

[1] Probability that the regression slope is not different from zero.

are for the two-sided test and since these same data will be used for another analysis the level of significance (α) is taken as 0.05/2.

Vaccaro and Ryther (1960) observed maximum concentrations of nitrite when both phytoplankton and nitrate were abundant at light limiting depths. *Tau* coefficients indicated that in the present study there were no significant correlations between either 1) the median chlorophyll *a* and the median nitrite concentrations below the thermocline ($P = 0.288$) or 2) the chlorophyll *a* and the nitrite concentrations at or within 5 m of the thermocline ($P = 0.490$).

Lorenzen (1967) suggested that a phaeo-pigment/chlorophyll ratio is indicative of herbivore grazing pressure, and since ammonium is the major nitrogenous excretion product of most marine crustaceans (Parry, 1960), we used the *tau* coefficient to examine the phaeo-pigment/chlorophyll ratios and ammonium and urea data from this study for positive correlation. If one assumes that the single pigment profile taken each sampling day is representative of the whole area

TABLE 3.—Comparisons of medians and variability of the nitrate, nitrite, ammonium, and urea results from stations sampled on the same day.

Nutrient	Period	Medians P	Variability P
Nitrate	A	>0.70	>0.40
	B	>0.70	<0.05
	C	>0.40	>0.20
Nitrite	A	>0.40	>0.70
	B	>0.70	>0.40
	C	>0.90	<0.05
Ammonium	A	>0.90	>0.90
	B	>0.40	>0.60
	C	>0.60	>0.10
Urea	A	>0.20	>0.90
	B	>0.10	<0.05
	C	>0.20	>0.60

for that day, it is reasonable to compare the phaeo-pigment/chlorophyll ratios with the best estimate of average ammonium and urea values for the same area. This is supported by the findings that the phytoplankton species composition was similar at all three stations and that the surface chlorophyll concentrations at Stations I and III were significantly correlated with the surface cell counts at Station II. Thus we paired the phaeo-pigment/chlorophyll ratios with the median ammonium and urea values at each depth for the same day in the following analysis. The phaeo-pigment/chlorophyll ratios were not correlated with the median ammonium concentrations in either Period A ($P = 0.189$) or Period C ($P = 0.171$) but were positively correlated in Period B ($P < 0.001$). The phaeo-pigment/chlorophyll ratios were not correlated with the median urea concentrations in Period A ($P = 0.382$), Period B ($P = 0.397$), or Period C ($P = 0.166$). Since each set of pigment and nutrient data have been used in two correlations, an appropriate α for significance is 0.05/2. Scatter diagrams for phaeo-pigment/chlorophyll ratios and the median ammonium and urea concentrations are presented in Figures 5 and 6 respectively.

DISCUSSION

Earlier studies in the Peru Current (McCarthy, 1970), in the central Pacific (McCarthy, 1971), and the present study have shown that great differences in both ammonium and urea occur on a vertical scale of a few meters. If during this study a small-scale inhomogeniety had been prevalent in the horizontal as well as vertical dimensions, it should have been evident both within and between stations made on the same day. If, on the other hand, there had been horizontal patches large with respect to a 1.5 km distance, the concentration at a particular depth should have been similar at both stations; this was apparently the case for nitrate, nitrite, and

TABLE 4.—Normal deviates (z) and corresponding probabilities (P) for comparisons between medians and variabilities of nitrate, nitrite, ammonium, and urea for all three periods.

Nutrient	Periods	Medians		Variabilities	
		z	P[1]	z	P[1]
Nitrate	A vs. B	3.80	**<0.005**	3.12	**<0.005**
	A vs. C	0.37	0.712	3.17	**<0.005**
	B vs. C	3.82	**<0.005**	2.72	**<0.005**
Nitrite	A vs. B	1.68	0.083	0.60	0.549
	A vs. C	0.48	0.631	4.89	**<0.005**
	B vs. C	1.83	0.067	2.31	**0.021**
Ammonium	A vs. B	0.57	0.569	2.36	**0.018**
	A vs. C	3.19	**<0.005**	1.40	0.162
	B vs. C	2.14	0.032	3.98	**<0.005**
Urea	A vs. B	5.58	**<0.005**	4.90	**<0.005**
	A vs. C	2.74	**<0.005**	1.02	0.308
	B vs. C	5.02	**<0.005**	4.97	**<0.005**

[1] P values are given for the two-sided test. To correct for multiple testing an α of 0.05/2 should be used. Significant differences are in bold type.

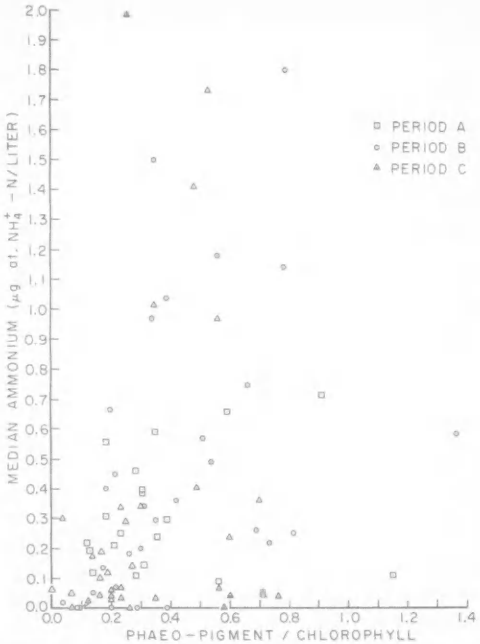

FIGURE 5.—Median ammonium concentrations and phaeopigment/chlorophyll ratios for Period A, Period B, and Period C.

to a lesser degree for ammonium but was not the case for urea.

Table 2 shows that the slopes for nitrate, nitrite, and ammonium regression equations contrasting the two stations sampled on any one day are positive and are significantly different from zero for each period. This implies that the values observed at each depth at one station on a particular day are positively correlated with those at corresponding depths at the other station. This resulted because the nitrate and nitrite profiles were nearly identical for the two stations on a single day and the ammonium profiles generally resembled each other. The regression slopes for the nitrate and nitrite data were all similar to 1.0, but the ammonium and urea slopes were occasionally far from unity. The regression slopes for the urea data were not significantly different from zero for either Period B or Period C. This analysis indicates that the patch structure of urea distribution is probably of a smaller horizontal scale than that of nitrate, nitrite, or ammonium. In comparing a particular depth at one station with the corresponding depth at another station, the two urea values are less likely to be similar than the ammonium values and considerably less than the nitrate or nitrite values.

The similarity of median values for the station pairs sampled on the same day (Table 3) suggests, on the other hand, a homogenous distribution for each nutrient over the sampling area; however, the stations showed markedly more resemblance in nitrate, nitrite, and ammonium than in urea. Comparisons also showed that within each period the median at Stations I and III were not different. This further supports the hypothesis of a smaller patch structure for urea since there was no persistent difference between stations with respect to urea, even though on any one day the stations may have differed significantly.

The three periods were based on the timing

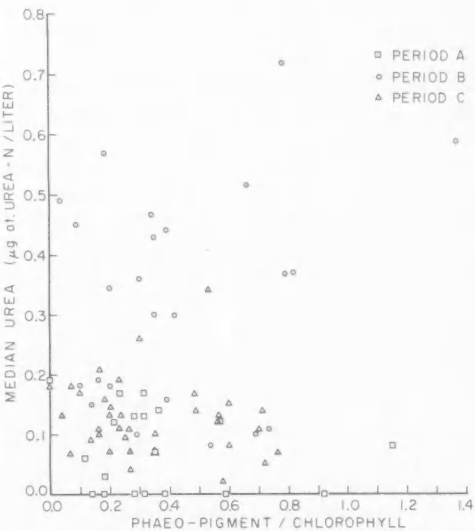

FIGURE 6.—Median urea concentrations and phaeo-pigment/chlorophyll ratios for Period A, Period B, and Period C.

of the shark infestation, and it is evident that the urea values were elevated significantly during Period B. It is unlikely that the significant differences in the medians and variabilities of the nitrate, nitrite, and ammonium values between periods were related to the presence of the sharks per se. The trends for each nutrient were markedly different: For nitrate the Period B median concentration was less than that in either Period A or Period C, for nitrite the median was unchanged, and for ammonium the median in Period B was greater than that in Period C but not different from that in Period A. Kamykowski (see footnote 4) presents data which suggests that a mechanism involving internal waves acting together with intermittent wind-related events (e.g., upwelling) can explain the pattern of increases in surface nitrate and corresponding decreases in surface temperature found in the study. Strasburg (1958) has shown that blue sharks in the central Pacific Ocean were found most frequently where the temperature was between 7° and 15°C; however, the temperature differences with respect to either time or depth which were encountered during the present study were not sufficient to provide an explanation for the shark infestation.

The nitrite regression equations contrasting the two stations sampled on the same day reveal that the dynamics of the nitrite production and utilization is uniform over the scale of a few kilometers. If the greater nitrite concentration below the thermocline represents a greater rate of production, our finding is consistent with the ideas put forth by Vaccaro and Ryther (1960) which suggest that nitrite liberation by phytoplankton in the presence of excess nitrate will be intensified at reduced light levels. The lack of correlation between the chlorophyll *a* and nitrite concentrations, however, implicates a complex interaction between components of the nitrite system.

The lack of correlation between ammonium and urea concentrations for Period A and Period C follows the pattern seen earlier in data from the English Channel (Newell, 1967), the Peru Current (McCarthy, 1970), and the central Pacific (McCarthy, 1971), but the strong positive correlation in Period B deserves further consideration. The median ammonium values for Periods A and B were not different, and although the rates must have been similarly balanced, the sources as well as rates of both supply and utilization could have been considerably different for the two periods. If the shark infestation was responsible for the elevated urea concentrations during this period, was it perhaps not also responsible for enough of the ammonium present to have produced the observed relationship? It would seem unlikely that the sharks were directly responsible since the selachii (modern sharks) are reported to excrete 80-90% of their nitrogenous end products as urea, 2-10% as ammonium, and the balance as amino acids and an unidentified fraction (Scheer, 1963). During Period B a squid (*Loligo opalescens*) spawn was noted off the coast of La Jolla. These usually last approximately 1 week, and during this time the adult squid reportedly do not feed (A. O. Flechsig, personal communication). Sharks collected during this period were found to have been feeding on squid (N. Marshall and G. Sullivan, personal communications), but it seems unlikely that the sharks were attracted to this area by the squid since such spawns are frequently noted without the presence of sharks. The squid spawns do, however, regularly attract birds (*Larus* spp.), and we also noted greater abundances of birds during this time. Nitrogen is excreted principally as ammonium by cephalopods (Barnes, 1963) and as uric acid by birds (Needham, 1931). It has been reported that uric acid is unstable in seawater and rapidly degrades to urea (Williams, 1970)[5] so the birds might have been an additional source of urea.

It is therefore possible that Period B was also unique with respect to the presence of ammoniotelic organisms which were either directly or indirectly supporting or supported by the shark population and which were in sufficient abundances to have resulted in the positive correlation between ammonium and urea concentrations.

[5] Williams, P. M. 1970. The stability of organic nitrogen compounds in seawater. University of California, Institute of Marine Resources. Research on the marine food chain progress report for U.S. Atomic Energy Commission Contract At(11-1)GEN 10, P.A. 20. Part 1, p. 8b. [Unpubl. manuscr.]

The strong positive correlation between phaeo-pigment/chlorophyll ratios and ammonium concentrations in Period B suggests that ammoniotelic herbivores were important, and perhaps the presence or abundances of these organisms were also related to the shark presence.

Another possible explanation for the positive correlation between ammonium and urea concentrations is that bacterial hydrolysis of urea during Period B was responsible for increased ammonium production. ZoBell and Feltham (1935) isolated marine bacteria capable of hydrolyzing urea from the same area used for the present study, but indirect evidence (McCarthy, in press) indicates that bacterial hydrolysis is probably of much less importance than phytoplankton uptake in the fate of urea in near surface waters off the coast of Southern California.

Fish, zooplankton, and phytoplankton have long been known to occur in schools, patches, and layers in near surface waters, and their spatial array probably contributed to the irregular distributions of both ammonium and urea seen in this study. On a scale of a few meters the input due to zooplankton and the utilization due to phytoplankton may approach an equilibrium, but the immediate effect of a large fish or fish school passing through a particular volume would be elevated ammonium and urea concentrations which would decrease with time at rates dependent on both diffusion and biological utilization. Since the blue shark has no urinary sinus (Dr. T. Enns, personal communication), both the branchial and the renal systems would be expected to release urea continuously. One can calculate both branchial (Boylan, 1967) and renal (Forster, 1967) excretion rates for *Squalus*, but it is questionable whether these rates would be representative of *Prionace glauca*. The major problem in attempting to estimate the shark urea production during the present study is, however, that of reliably estimating the shark biomass.

An increased rate of ammonium or urea production in a parcel of water will not necessarily be reflected in an increased seawater concentration of the metabolite. To the extent that rates of utilization are dependent on substrate concentrations, e.g., nitrogen uptake by phytoplankton, then an immediate increase in the rate of utilization might be expected in response to an increased rate of production. There are no sewage outfalls in the vicinity of La Jolla Bay, but the supply of ammonium and/or urea to waters proximate to such discharges may result in significant enrichment with these nutrients (Eppley et al., in press).

Because of the spatial variability in both supply and utilization and the low concentrations usually encountered, it is difficult to interpret, or even detect, short-term changes in ammonium and urea concentrations in near-surface seawater. Surface waters into which fish and crustaceans migrate daily in some degree of synchrony to feed is one setting in which such changes might be expected, and have been observed. Beers and Kelly (1965) presented data which suggested a correlation between variations in ammonium concentrations in the upper 500 m of the Sargasso Sea and the diurnal migration of zooplankton, and Emmet (1969) referred to unpublished work which showed that a diurnal maximum in urea concentration occurs in open ocean surface waters early in the morning.

If, as Lorenzen (1967) has suggested, a phaeo-pigment/chlorophyll ratio is indicative of herbivore grazing pressure, the significant correlation between this ratio and ammonium concentrations reported in Period B of this study might imply that (1) both fecal material and ammonium excreted by herbiverous zooplankton have residence times which are similar, or (2) ammonium is released with the degradation of herbivore fecal pellets. The lack of correlation in Periods A and C might imply that herbivores were not significant sources of ammonium during these periods. The lack of correlation between phaeo-pigment/chlorophyll ratios and urea concentrations might imply that (1) herbivore excretion is not an important source of urea, (2) the residence times of phaeo-pigments and urea are sufficiently different to mask any association, (3) urea excreted by nonherbivores obscured a relationship between phaeo-pigment/chlorophyll ratios and urea concentrations, or (4) urea is not released with the degradation of herbivore fecal pellets. Herbivores zooplankton have been shown to release substantial quantities

of urea (Corner and Newell, 1967; McCarthy, 1971) so the lack of correlation with phaeo-pigments might further implicate the blue sharks as the major source of urea during Period B. The residence times of ammonium and urea may well differ since ammonium is utilized readily by all marine phytoplankters whereas urea is utilized by only some species and even then uptake may be partially suppressed by certain concentrations of nitrate or ammonium (McCarthy and Eppley, in press). It is not known whether urea is released in fecal pellet degradation.

The data from the present study do not show whether the relationship between the presence of the blue sharks and the elevated urea values in Period B is one of cause and effect. If the sharks were a significant source of urea, this may provide an explanation for the similarity in urea concentrations above and below the thermocline, the more irregular distribution of urea, and perhaps the lack of correlation between phaeo-pigment/chlorophyll ratios and urea concentrations. Without estimates of urea input due to excretion by sharks, other fish, zooplankton, and possibly birds, and rates of urea utilization for phytoplankton, the net effect of the shark population's contribution to urea production cannot be rigorously evaluated.

While this manuscript was in review, Remsen (1971) published the results of urea analyses for samples collected from both the eastern tropical Pacific Ocean and coastal waters off northeastern United States. The concentrations he detected were generally higher than those reported either previously or in this communication but his conclusions as to the biological significance of urea in the marine environment are not at variance with those presented here

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FISH SOLUBLES AS A PARTIAL SUBSTITUTE FOR MILK AND MILK BY-PRODUCTS IN LIQUID RATIONS FOR NEONATAL ANIMALS

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ABSTRACT

This paper presents (1) a literature review of the use of fish protein in milk replacers for neonatal animals, (2) a list of criteria for proteins used in milk replacers, and (3) reports on three experiments in which menhaden fish solubles were partially substituted for milk protein in milk replacer rations.

Initial experiments reported here indicated that low levels (5%) of fish solubles produced equal calf growth when they replaced a similar amount of milk products in veal calf rations. However, the addition of 15% freeze-dried solubles at the expense of dried skim milk (DSM) did not produce satisfactory growth in young lambs. This was true even when lecithinated soy flour or delactosed whey powder supplemented part of the protein in the ration. Therefore, it is concluded that if significant quantities of fish protein are to be incorporated into milk replacer rations, protein of higher quality than that present in fish solubles must be used.

Attempts to develop a product suitable for replacing fresh whole milk for feeding calves occurred in the early 1900's. However, due to the lack of knowledge regarding calf nutrition, these products were not very satisfactory. By the end of the 1940's knowledge of the nutritional needs of calves had developed to a point that made it possible for satisfactory substitutes for whole milk to be marketed. Today, milk replacers have been refined to such an extent that many dairymen are reporting faster weight gains by feeding milk replacers instead of fresh whole milk. Several important developments contributed to this improved performance. They include: (1) the use of antibiotics, (2) the use of stabilized vitamins, and (3) the increased use of dried milk proteins. Recently the use of milk replacers has increased because of automation of feeding techniques, their ease of handling and storing, improved formulations, and the increased emphasis on salvaging orphan and runt animals which would have previously have been lost by the producer.

Manufacturers of milk replacers depend largely upon dried skim milk (DSM) and dried whey as the major ingredients. Because of the continued high market price of DSM throughout the world, feed manufacturers are looking for lower priced substitutes to be used in their milk replacer formulations. The superior value of feeding milk solids as compared to vegetable feedstuffs in milk replacers has been well demonstrated (Huber, 1965). Therefore, it is the purpose of this paper (1) to briefly review work reported in the literature, (2) to list the criteria necessary for proteins used in milk replacers, and (3) to report the results of our work to determine if fish solubles can be partially substituted for milk and milk products in liquid rations for neonatal animals.

REVIEW OF RECENT LITERATURE

Harshbarger and Gelwicks (1965) reported that calves fed a milk replacer containing 20% low-fat fish meal performed as well as calves that were receiving a 50% DSM replacer. Average daily gains and feed intakes at 12 weeks of age were similar for all calves studied that received either DSM or fish meal.

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Huber and Slade (1967) substituted varying levels of fish protein (defatted fish meal) for skim milk protein in calf milk replacers in growth and balance studies. They also investigated the effect of varying levels of dietary fat in combination with fish protein on growth response. Their data showed that average daily gains and feed efficiencies were not significantly different when fish protein replaced up to 40% of the dietary protein. However, when fish protein replaced from 60 to 67% of the dietary protein, significant decreases ($P<0.01$) occurred. Increasing fat in the rations from a 10 to 20% level caused a linear increase ($P<0.05$) in gains. However, no interaction between protein source and fat level was detected. Furthermore, as the amount of fish protein in the milk replacer increased, digestibilities of dry matter, crude protein, fat, and ash decreased. Only when fish protein furnished 100% of the dietary protein was there a significant depression ($P<0.05$) in the percent of digested nitrogen retained. Crude protein in the fish concentrate was reported to be 80% digestible compared to 90% for skim milk protein.

Williams and Rust (1968) reported a study with four different formulations of experimental milk replacers, and their results supported the findings of Huber and Slade (1967). Defatted fish flour provided from 14 to 42% of the total protein in these experimental rations. Total protein, fat, and digestible nutrients were equal in all experimental rations and were similar to those of the standard milk replacer ration. At the termination of the 42-day experiment, they reported that calves fed the various experimental milk replacers gained similar amounts of weight and they were comparable to calves on the conventional milk replacer. These results indicated that fish protein could be effectively utilized and provide up to 42% of the protein in the ration.

Gorrill (1970) conducted similar studies on the use of fish protein in milk replacers. Fish protein concentrate (FPC), which was in this case isopropanol extracted fresh whole herring, accounted for 50% of the protein in the fish containing milk replacer. He also fed a dry starter on a restricted basis and hay ad lib. with the liquid diet and found that at least 50% of the milk replacer protein could be supplied by FPC with no significant difference in weight gains from those of whole milk or an all-milk product replacer ration.

In European countries there has been increasing interest in developing fish products which could be utilized in milk replacer rations. France is currently producing 550,000 to 600,000 tons of milk replacer per year which includes the use of fish protein in veal diets. In particular, two French feed manufacturers began marketing milk replacers containing fish protein in the form of FPC or autolyzed fish concentrate in an effort to use a lower priced animal protein.

CRITERIA FOR PROTEINS IN MILK REPLACERS

Generally, there are eight criteria that will have to be met by the producers of fish protein before feed manufacturers will consider using such protein in milk replacer formulas.

First, the fish protein must be highly available to the animal. At present, a wide range of values has been reported on fish protein in milk replacer rations. Reports of from 50 to 80% digestible protein can be found in the literature. Since skim milk has a digestible protein value of about 90%, it is imperative that fish products have a protein digestibility as close to this as possible.

Second, the product must be of uniform quality and be available throughout the year in quantities large enough to meet demands.

Third, fish protein must be lower in cost than milk protein or equal if DSM is scarce. Manufacturers will be willing to use fish protein only if its substitution for milk products gives a reduction in price of the milk replacer. There is always risk involved when changing formulas, and the manufacturers must be shown an economic advantage before they will take that risk.

Fourth, the fish protein must be suspendable in water when used in the formulation. With the increased application of automatic feeding devices in the rearing of neonatal animals, a completely suspendable milk replacer is important. The functional properties of current FPC and

fish meals must be improved to develop a product that will remain in suspension.

Fifth, fish proteins must be odorless, relatively free from a fishy taste, have a light color, and be stable. Many manufacturers of milk replacers feel that the fat content of the fish product must be kept as low as possible (less than 1%) to maintain the stability of fish protein. Some manufacturers suggest additions of antioxidant since they have experienced a deterioration of autolysates after storage. However, it has been reported by Ronning (1970) that hydrogenated fish oils with an iodine number of 80 are of value in high-energy milk replacers. Through the addition of higher levels of α-tocopherol (Vitamin E) and by reducing the levels of unsaturated fatty acids by hydrogenation, he was able to feed calves up to 26.2% fish oil with no detrimental effects.

Sixth, the bone content of the fish protein product must be relatively low. Producers of milk replacers indicate they want a final product with less than a 10% mineral content. More importantly, they want this concentration of minerals to remain constant from one batch of milk replacers to another. Therefore, the major individual ingredients in the milk replacer must have a constant mineral composition. In addition, if a milk replacer containing fish protein is to be fed for the production of veal calves, it must be low in iron (less than 50 ppm). The preferred paleness of veal muscle tissue results from a state of anemia due to the low iron content of the rations fed to veal calves. At present, the iron content of FPC made by isopropyl alcohol extraction may vary between 147 and 770 ppm (Finch, 1970). However, a large part of this iron comes from mechanical contamination (i.e., grinding) and may be of a type that is poorly available to animals. If the iron content can be made unavailable by adding an iron-chelating agent, as suggested by Saheb and Charpentier (1970), a high-quality veal meat may be produced. Inasmuch as the major market in the United States is for replacement animals, iron should not be a problem.

Seventh, the moisture content of the fish protein must be kept low to prevent lumping of the milk replacer and other texture changes during storage. Most milk replacers contain 5% moisture or less.

Eighth, fish protein to be used in milk replacers would have to have a reasonably low bacterial plate count because neonatal animals are quite susceptible to digestive upsets. A low moisture content would help to keep bacterial growth to a minimum.

EXPERIMENTAL RESULTS

Our research at the National Marine Fisheries Service, College Park Laboratory was conducted to determine the feasibility of using fish solubles in milk replacer rations.

EXPERIMENT I

The objective of the first study was to determine the effect of partially substituting condensed menhaden fish solubles in a commercial ration for veal calves. Four Holstein bull calves were placed individually in stalls at 3 days of age. Two of the calves were fed a commercial veal ration, containing 24% protein and 20% fat. The remaining two calves received the same commercial ration with low-fat (3%) menhaden fish solubles replacing 5% of the ration on an equal weight basis. The calves were full-fed twice daily. Table 1 shows the results of this experiment. At 75 days of age, the milk replacer plus fish solubles group had average daily weight gains (0.93 kg) and feed conversions (1.41) comparable to those of the all-milk products replacer. However, due to the small number of

TABLE 1.—Experiment I. Weight gains and feed consumptions of calves fed either control milk replacers or milk replacers containing 5% fish solubles.

	Control	Fish solubles
Average body weight, kg		
Initial	39.09	36.82
75 days	105.00	106.36
Average daily weight gain, kg		
36 days	0.82	0.72
75 days	0.88	0.93
Average feed (dry)/gain		
36 days	1.09	1.20
75 days	1.53	1.41

animals used in this study it cannot be interpreted clearly that supplementation with fish solubles produced a superior product, but it is apparent that when fish solubles replaced 5% of an all-milk replacer commercial ration, growth rates and feed conversions were at least equal to the control that contained all-milk protein.

A triangular organoleptic test for flavor with 12 panelists was performed on 1.91-cm slices from the liver, loin ends (chops), and rounds (cutlets) of all test animals. Table 2 shows the results of the organoleptic evaluations. When the data from this test were statistically analyzed by the Student's *t*-test, a significant flavor difference ($P<0.05$) was found between the two groups. Meat from the experimental animals appeared to have more beef flavor rather than the desirable bland flavor associated with veal. Likewise, the meat from the experimental animals had a noticeably darker color than that of the control animals. This difference was probably due to the high level of minerals present in the fish solubles, especially iron.

TABLE 2.—Experiment I. Flavor test of meat from veal calves fed either control milk replacers or milk replacers containing 5% fish solubles.

	Control	Fish solubles
Cutlet		
Replication I	[1]7.67 ± 1.07	6.00 ± 1.71
Replication II	6.50 ± 1.88	6.00 ± 1.41
Average	[2]7.08 ± 1.61	6.00 ± 1.53
Chops		
Replication I	7.92 ± 1.00	6.50 ± 2.20
Replication II	7.42 ± 1.56	6.25 ± 1.86
Average	[2]7.67 ± 1.31	6.38 ± 2.00
Liver		
Replication I	6.25 ± 1.91	6.67 ± 1.83
Replication II	5.92 ± 2.19	6.33 ± 1.83
Average	6.08 ± 2.02	6.50 ± 1.79

[1] All values represent a scale of from one (unacceptable flavor) to eight (highly acceptable flavor).
[2] Significant at $P<0.05$.

EXPERIMENT II

The objective of this experiment was to study the feasibility of supplementing dried whey product, DSM, and/or soy flour with dry, low-fat menhaden solubles in lamb rations. Fifteen crossbred lambs, 2 to 7 days old, were placed on a commercial liquid, all-milk replacer ration for a preliminary period of 1 week. At the end of this period, lambs were allotted by weight, sex, and age to one of three experimental rations. The composition of the rations is shown in Table 3. All rations contained 24% protein, 20% fat, vitamins, minerals, antibiotic, and antioxidant. All lambs were given as much liquid feed as they could consume twice daily. Every 7 days body weights were measured, and feed consumption data were recorded daily. The experiment was terminated after 28 days. The average weight gains are shown in Table 4. Ration II (soy, whey product, and fish solubles) produced a growth response equal to 28.6% of that of Ration I (DSM and whey product), and Ration III produced an 82.9% response compared with Ration I.

TABLE 3.—Lamb ration formulations used in Experiments II and III.

Ingredients	Ration I	Ration II	Ration III
	%	%	%
Dried skim milk	65.00	--	30.00
Whey product	3.80	29.74	19.90
Menhaden fish solubles (freeze-dried)	--	15.00	15.00
Lecithinated soy flour	--	20.00	--
Glucose[1]	8.32	16.47	13.02
Emulsified lard	19.63	15.54	18.83
Vitamin premix[2]	1.00	1.00	1.00
Mineral premix[3]	1.00	1.00	1.00
Antibiotic premix[4]	1.00	1.00	1.00
Antioxidant premix[5]	0.25	0.25	0.25
	100.00	100.00	100.00

[1] Cerelose, Corn Products Co., New York. (Reference to trade names in the publication does not imply endorsement of commercial products by the National Marine Fisheries Service.)
[2] Vitamin premix provides per kilogram ration: A, 3,300 IU; E, 22 IU; D_3, 66 IU; B_{12}, 2 mg; niacin, 1,400 mg.
[3] Mineral premix provides per kilogram ration: iron, 42 mg; manganese, 19 mg; zinc, 50 mg.
[4] Antibiotic premix provides 55 mg terramycin per kilogram of ration.
[5] Nine parts glucose to one part Ethoxyquin.

EXPERIMENT III

A third experiment was conducted using Rations I and III, to confirm the previous observations. Ten lambs were placed on each treatment at 2 days of age. The ration formulations were the same as those in the previous experiment and contained 24% protein, 20% fat, vitamins, minerals, antibiotic, and antioxidant. A mixture of the dry ration with water (1:5) was fed

TABLE 4.—Experiments II and III. Weight gains of lambs fed either control milk replacer rations or those containing fish solubles and soy flour.

	Experiment II			Experiment III	
	Control	Fish solubles	Fish solubles + soy flour	Control	Fish solubles
Average weight gain, kg					
Initial	5.64	6.59	5.77	4.88	5.20
14 days	1.72	1.00	0.36	3.13	1.04
28 days	4.50	3.59	1.27	5.75	3.01
Average daily weight gain, g					
14 days	120	70	30	220	70
28 days	160	130	40	200	100

throughout the entire experiment which was terminated after 28 days.

Table 4 shows the results of this experiment. The average daily weight gains of lambs fed the control ration and those fed the fish solubles plus milk products ration were 200 g/day and 100 g/day, respectively. The combined results indicate that the ration containing 15% freeze-dried menhaden solubles only produced a 58% growth response as compared to that of the control ration. At the 15% level of incorporation, dried fish solubles will not effectively replace the DSM protein. It should be noted that this level of incorporation corresponds to 30% on an "as is" basis (before freeze drying) which is an extremely high feeding level for fish solubles.

The College Park Laboratory is continuing to study the feasibility of using fish proteins, such as partially hydrolyzed press cake, defatted fish meal, and lower grade forms of FPC as substitutes for milk products in liquid rations for neonatal animals.

CONCLUSIONS

The data indicate that a higher quality protein than that in fish solubles is necessary in order to incorporate significant quantities of fish protein in milk replacer rations.

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COMPARISON OF THE ASSIMILATION OF DIFFERENT DIETS BY *PENAEUS SETIFERUS* AND *P. AZTECUS*

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ABSTRACT

Juvenile penaeid shrimp showed high and comparable assimilation efficiencies (80-85%) on a variety of plant and animal diets. In general assimilation efficiencies for proteins and lipids were consistently high; for carbohydrates, low. Organic assimilation per gram organic weight of white shrimp, *Penaeus setiferus*, proceeded at 3.7 mg hr^{-1} on an axenic diatom and 8.4 mg hr^{-1} on an artificial diet. The assimilation efficiency was lower for shrimp feeding on the algal mat coating *Spartina alterniflora* than on two components of the mat. Feeding mechanisms and probable natural diets are discussed as a basis for further study.

In tidal estuaries where consumers are heavily dependent on an input of autochthonous and allochthonous detritus, the trophic structure is obscured by the seemingly omnivorous habit of many of the residents. Historically, the feeding habits of these omnivores have been investigated by examination of gut contents, correlation of numbers of omnivores with type of benthic community, and comparison of the types of foods available in different areas with the species composition of consumers (Darnell, 1964; Corner and Cowey, 1968; Edmondson and Winberg, 1971). While these investigations have been valuable and are the bases of our present understanding of estuarine communities, it should be noted that a large percentage of the foregut contents of many estuarine species is unidentifiable (Darnell, 1964).

In Louisiana estuaries shrimp is seasonally one of the dominant organisms and commercially the most important one. Although speculation about the diet of juvenile shrimp in inland waters has been widespread, the datum base in the literature for these speculations is not convincing. Studies of shrimp gut contents (Flint, 1956; Darnell, 1964) seem to indicate that the organism ingests the dominant materials in the sediments. In Lake Ponchartrain, for instance, Darnell (1961) found that 58% of the stomach contents of adult white shrimp was unidentifiable detritus. Little is known, however, about the ability of shrimp to digest different food sources. Nose (1964), working with *Penaeus japonicus*, reported a higher assimilation efficiency of animal than of plant proteins. Fujii et al. (1963) and Dall (1965) have studied the activity of digestive enzymes of several species of shrimp.

This study concerns the assimilation by the white shrimp, *Penaeus setiferus*, and the brown shrimp, *P. aztecus*, of the organic components of four different defined diets and a natural substrate. Except for the rates reported, the assimilation parameters were measured by a modification of the ratio method of Conover (1966a). Therefore, quantitative recovery of food or feces was not required.

METHODS AND MATERIALS

CALCULATION OF ASSIMILATION PARAMETERS OF ORGANIC MATERIAL

Direct calculation of net assimilation is difficult in aquatic environments because of the need to measure quantitatively both ingestion

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and egestion of food by the organisms under study. Recently, this problem was circumvented by Conover (1966a). He developed a method for determining the net assimilation efficiency of organic matter (U')[3] without quantitative recovery of either the uneaten food or the feces, based upon the assumption that the assimilation process affects only the organic portion of the food. This is a critical assumption since the ash in the food is treated as an inert label to measure the quantity of food ingested. If this assumption is made, the general definition of assimilation efficiency,

$$U' = \frac{(I - N)}{I} \times 100 \qquad (1)$$

where I is the organic weight ingested, and N is the organic weight egested, reduces to Conover's equation,

$$U' = \frac{(F' - E')}{(1 - E')\ (F')} \times 100. \qquad (2)$$

$F' = I/F$ = ratio of organic weight to dry weight of food ingested, and $E' = N/E$ = ratio of organic weight to dry weight of material egested. Symbols are defined in Table 1. Conover (1966a) and Corner, Cowey, and Marshall (1967) found close agreement between assimilation efficiencies calculated by the ratio method and direct quantitative recovery of food and feces. In both cases the comparison was made with zooplankton feeding on phytoplankton.

Assimilation, however, is a complex function controlled by (1) the net assimilation efficiency (U'), or digestibility; (2) the concentration of ash; and (3) the rate of ingestion. For our work, we found it helpful to modify Equation 2 to consider (a) the combined effect of digestibility and organic concentration upon the amount of food assimilated and (b) the net assimilation rate. A further modification was required to consider the assimilation of specific organic moieties. The reasoning and equations are presented briefly below. A more detailed derivation can be found in Condrey (1971).

[3] Conover uses the term "assimilation efficiency." Strictly this should be "net assimilation efficiency" since it measures the difference between assimilated organics and previously assimilated organics which are lost in the feces (peritrophic membrane, digestive secretions). The two terms are used interchangeably in this paper.

TABLE 1.—List of symbols.

Symbol	Explanation
A	Net organic weight assimilated.
A_X	Net amount of an organic moiety assimilated.[1]
E	Dry weight of feces.
E'	Ratio of organic weight to dry weight of feces. (N/E).
e'_X	Ratio of organic moiety to dry weight of feces.
F	Dry weight of food.
F'	Ratio of organic weight to dry weight of food. (I/F).
f'_X	Ratio of organic moiety to dry weight of food.
I	Organic weight ingested.
I_X	Quantity of an organic moiety ingested.
N	Organic weight egested.
N_X	Quantity of an organic moiety egested.
R	Ratio of organic weight to oxidizable carbon.
r_i	Ratio of an organic moiety to total organic weight of food. (I_X/I).
r_n	Ratio of an organic moiety to total organic weight of feces. (N_X/N).
U'	Percent assimilation efficiency of total organic weight (A/I)(100).
U'_X	Percent net assimilation efficiency of an organic moiety. (A_X/I_X)(100).

[1] When denoting a specific organic moiety the subscript X is replaced by P for protein, L for lipid, CH_2O for carbohydrates, C for oxidizable carbon.

FEEDING EFFICIENCY

A comparison of the amount of organic matter assimilated per unit of diet ingested is:

$$A/F = (F')\ (U'/100). \qquad (3)$$

This is a valuable type of representation for simultaneous comparison of the relative organic weight assimilated on different diets, as is demonstrated in Figure 1. The ratio is termed "feeding efficiency" for lack of a better term. Note that whereas U' is a ratio of organic weight assimilated to organic weight ingested, the feeding efficiency considers the effect of differing organic concentrations in the diet. As will be shown, this may be of considerable importance when comparing net assimilation of diets sim-

ilar in organic content but differing in ash concentration.

NET ASSIMILATION RATE

Where either the ingestion or egestion rate is determined, Equation 2 can be readily adapted to yield the net assimilation rate. For the latter case, the organic weight egested (N) is defined as the product of the ratio of organic matter to dry weight egested (E') and dry weight egested (E). Net assimilation, in terms of egested material, is

$$A = \frac{(E)\,(E')\,(U')}{(100 - U')} \qquad (4)$$

where $(100 - U')$ is the percentage of ingested organic food that is egested. When E is reported in terms of dry weight of feces deposited per unit time, Equation 4 yields the rate at which net assimilation of organic matter proceeds.

ASSIMILATION PARAMETERS FOR SPECIFIC ORGANIC MOIETIES

NET ASSIMILATION AND FEEDING EFFICIENCIES OF AN ORGANIC MOIETY

The determination of the net assimilation efficiency of an organic moiety (U'_x) independent of U' is not possible by direct substitution in Conover's equation (Equation 2). This becomes clear if one considers the equation for net assimilation efficiency of a specific organic moiety.

$$U'_x = \frac{I_x - N_x}{I_x} \times 100 \qquad (5)$$

where I_x is the amount of the moiety ingested and N_x the amount of the moiety egested. Conover was able to derive Equation 2 from Equation 1 by setting I equal to total particulate matter egested minus its ash. Clearly this relationship does not hold for I_x and N_x in Equation 5.

Let r_i and r_n be ratios of the weight of the organic moiety of interest to the total organic weight of the food and feces respectively. Then

$$I_x = r_i I = r_i(FF'), \qquad (6)$$

and

$$N_x = r_n N = r_n(FF')\,(1 - U'/100). \qquad (7)$$

Substituting in Equation 5:

$$U'_x = \frac{r_i - r_n\ (1 - U'/100)}{r_i} \times 100. \qquad (8)$$

From Equations 6 and 7 the feeding efficiency of an organic moiety is:

$$A_x/F = F'\ [r_i - r_n\ (1 - U'/100)]. \qquad (9)$$

NET ASSIMILATION RATE OF AN ORGANIC MOIETY

The amount of a particular organic moiety egested can be defined as

$$N_x = (E)\,(E')\,(r_n). \qquad (10)$$

Similarly,

$$I_x = \frac{(E)\ (E')\ (r_n)}{(1 - U'/100)}. \qquad (11)$$

When E is defined as the amount of feces deposited per unit time, Equations 10 and 11 become rate equations for determining the amount of a moiety ingested and egested per unit time. The assimilation rate of the moiety is the difference between the values of I_x and N_x.

EXPERIMENTAL TECHNIQUES

FEEDING

Juvenile shrimp, *Penaeus setiferus* and *P. aztecus*, 24 to 83 mm long, were collected from Barataria Bay, La., and maintained in aerated aquaria containing acid-washed quartz sand, filled with membrane-filtered bay water at 20°-23°C.

Test foods were given to shrimp which had been starved for 12 hr, in groups of 10 to 14, unless otherwise noted. Animals were allowed to feed ad lib. for 12 to 36 hr. Fecal material

was collected soon after voided with a fine-tipped eye dropper. It was placed in a Syracuse dish in saline solution (0.6% $CaCl_2$, 2.5% NaCl) and, under a dissecting microscope, cleaned of all adhering extraneous material such as sand grains. Torn or broken strands were rejected. To remove adherent salts, the fecal material was then washed with 3% ammonium formate on preignited, washed, and tared glass fiber filters and dried at 65°C to constant weight. Reproducibility of blank filters washed with two 1-ml aliquots of 3% ammonium formate varied from 0.01 to —0.05 mg. No correction was made for the sporadic weight loss of the blanks. Dried samples were frozen until analyzed. Sufficient fecal material was obtained for 2-8 replications of each analysis. Analyses of the fecal pellets produced on the detritus diet used 0.2 to 1 mg samples. The high variability of results with these samples was greatly reduced by increasing sample size. Therefore, subsequent analyses of fecal material employed 1 to 10 mg feces per replication. Errors in samples less than 1 mg in weight were presumed to be caused by inhomogeneity of fecal material and magnification of the absolute errors involved in weighing and chemical analyses. Replications for each analysis were chosen from fecal samples collected at different feeding intervals. There was no indication of a change in the assimilation efficiency of a given diet with time.

To avoid undue handling, shrimp were sized and identified to species only after feeding. Therefore, feeding occurred with mixed sizes and species. Three diets—diatom, Chow, and algal mat—were fed to white shrimp only, and two diets—detritus and AF-1—were fed to white and brown shrimp. In tests in which individual shrimp were fed differences were not found in assimilation efficiency due to size (see for instance Table 7) or species. Therefore, the results reported here are assumed to apply equally to both species within the size range used.

FEEDS

The digestibility of four defined diets, two artificial and two natural, was investigated. In addition, in a fifth test, shrimp were allowed to graze on the algal community coating the base of culms of the oyster grass, *Spartina alterniflora*, and the assimilation of this food source was measured.

The four defined diets were: (1) an axenic culture of the periphyton diatom, *Cylindrotheca fusiformes*; (2) a heavily bacterized culture of the same diatom (termed hereafter "detritus"); (3) AF-1,[4] an artificial food consisting of rice bran (52.0%), shrimp meal (30.5%), fish meal (8.0%), fish solubles (2.0%), mineral mix (2.0%), soy protein (3.0%), and Calgon (0.2%); and (4) Trout Chow,[5] consisting primarily of fish meal, fish solubles, soybean meal, ground wheat, and ground yellow corn, with a guaranteed minimum analysis of 40% crude protein, 2.5% crude fat, and 5.5% crude fiber.

The method used rests on the assumption that the food is representative of the ingested material, that is, that selection does not occur. In order to minimize the possibility that the shrimp could select by sorting of particles, and to prevent dispersion and suspension of the defined diets during feeding, all these diets were bound by mixing with a 2% algin solution (Meyers, Butler, and Hastings, 1972). The mixture was extruded through a syringe of 1-mm pore diameter into a 0.6 to 1.2% $CaCl_2$ solution. The calcium ion sequestered the algin, producing either strands or small spheres of bound food which were readily accepted by the shrimp. Details of this method are discussed at length in the aforementioned article.

CHEMICAL ANALYSES

After drying, samples of food and feces were digested along with the glass fiber filters on which they were isolated. Filter blanks carried through the same analytic procedures indicated no detectable contamination from this source.

[4] Prepared by Dr. Samuel P. Meyers and D. Butler, Department of Food Science, Louisiana State University, Baton Rouge, La.

[5] Ralston Purina Company, St. Louis, Mo. Reference to trade names in the publication does not imply endorsement of commercial products by the National Marine Fisheries Service.

Oxidizable carbon analyses were by the wet dichromate procedure of Johnson (1949) as reviewed by Strickland and Parsons (1968). Glucose was used as a standard. The limitations of this method are discussed by Johnson (1949). Total nitrogen was determined by a micro-Kjeldahl technique with ninhydrin color development; lipids in terms of fatty acids by saponification followed by complexing with pinacyanol; and carbohydrates in terms of glucose using the anthrone reaction. Methods are those described by Strickland and Parsons (1968). Protein was estimated by multiplying the nitrogen values by 6.25.

Ash-free dry weights were determined from samples heated to dryness after addition of 1 ml of nitric acid and then ignited at 500°C (2 hr). For the defined diets (i.e., diatom, detritus, AF-1, and Trout Chow), F' values were obtained from samples treated in this manner. Because of small sample size, accurate determinations of ash-free dry weight could not be made for fecal material. Therefore E' was calculated from oxidizable carbon in the feces, assuming that the ratio of total organic weight to oxidizable carbon (R) determined for the food was true also for the feces. Markedly different diets yielded a ratio of oxidizable carbon to organic weight of 1.92 to 2.33 (Table 2). This gives an estimate of the likely error involved in the assumption. Insufficient material was obtained from the algal mat for ash-free dry weight determination of F', and this value was estimated by multiplying the oxidizable carbon concentration by 2.

Analyses of variance were performed on the raw data and are shown as standard errors of the mean in the appropriate tables.

RESULTS

The effect of using 10 to 14 shrimp as a group in each test was to average individual variation. As shown in Table 3 variation in fecal analyses among subsamples within the tests was extremely low, the coefficient of variation usually less than 5%. Individual variability is shown in the results of the feeding study on a natural algal mat (Table 8). In this test, the substrate presented to the shrimp was not homogeneous. The coefficient of variation of U' for individual shrimp fed on diets ranging from 20 to 31% oxidizable carbon was 16%.

Comparison of total organic concentration to the sum of protein, lipids, and carbohydrate re-

TABLE 2.—Chemical analyses of defined diets.

Diet	Total organic wt	Oxidizable carbon	Organic wt	Nitrogen	Nitrogen	Lipids	Lipids	Carbohydrates	Carbohydrates
	Dry wt	Dry wt	Oxidizable carbon	Dry wt	Organic wt	Dry wt	Organic wt	Dry wt	Organic wt
	F'	f'_C	R	f'_N	r_i	f'_L	r_i	f'_{CH_2O}	r_i
	%	%		%	%	%	%	%	%
Diatom	85 ± .01[1]	43 ± 1.2	1.98	7.6 ± .04	8.9	19 ± 1.4	22	5.7 ± 0.4	6.7
Detritus	80 ± .06	42 ± 1.1	1.92	5.1 ± .46	6.4	20 ± 4.8	25	11 ± 0.4	14
AF-1	82 ± .00	35 ± 1.3	2.33	5.4 ± .00	6.6	7.4 ± 1.3	9.1	20 ± 0.3	24
Chow	89 ± .00	46 ± 2.1	1.93	7.2 ± .06	8.1	4.6 ± 0.1	5.1	25 ± 0.0	28

[1] Figures are mean values from 2-8 determinations ± standard error.

TABLE 3.—Chemical analysis of feces produced by shrimp fed on defined diets.

Diet	Oxidizable carbon	Nitrogen	Nitrogen	Lipids	Lipids	Carbohydrates	Carbohydrates
	Dry wt	Dry wt	Organic wt	Dry wt	Organic wt	Dry wt	Organics
	e'_C	e'_N	r_n	e'_L	r_n	e'_{CH_2O}	r_n
	%	%	%	%	%	%	%
Diatom	22 ± 1.1	2.4 ± .00	5.6	0.69 ± 0.1	1.7	9.1 ± 1.3	21
Detritus	20 ± 6.2	4.1 ± .10	10.7	8.1 ± 0.9	23	13 ± 1.5	35
AF-1	29 ± 1.3	3.4 ± .02	5.1	3.3 ± 0.3	5.0	18 ± 2.4	27
Chow	32 ± 0.8	3.4 ± .02	5.5	3.5 ± 0.1	5.7	21 ± 2.2	34

vealed that in the foods 75 to 85% of organic weight was accounted for. These results were consistent, indicating the presence of organic components which are not detected by any of the three methods. Recovery of organic fractions from fecal material was, with the exception of the detritus diet, lower than with foods, ranging from 60 to 74% of organic weight of the feces. The implication is that the unaccounted organic components of the food are also poorly assimilated by shrimp and accumulate in the feces. We have not been able to identify the chemical nature of these components.

DEFINED DIETS

Net Assimilation Efficiency of Total Organic Weight and of Organic Moieties

Tables 2 and 3 show results of chemical analyses of the defined diets and of the feces of shrimp fed on these diets. Data are presented not as amounts, but as percentages for incorporation into the ratio equations.

Assimilation efficiencies calculated from these data (Table 4) revealed that the organic matter of three of the diets was assimilated with a high degree of efficiency. These diets were the diatom, 87%; the detritus, 85%; and the Chow, 80%. The similarity in overall digestibility suggests an adaptive trituration and enzymatic apparatus operating as efficiently against diatom frustules as against bacterial cell walls. The ability to assimilate effectively varied diets of animal, vascular plant, and algal origin denotes the true omnivorous habit of the shrimp.

TABLE 4.—Net assimilation efficiencies of total organic matter, protein, lipids, and carbohydrates for shrimp fed on defined diets.

Diet[1]	Total organic wt U'	Proteins U'_P	Lipids U'_L	Carbohydrates U'_{CH_2O}
	%	%	%	%
Diatom	87	92	99	59
Detritus	85	75	86	63
AF-1	55	65	75	49
Chow	80	86	78	76

[1] Diatom and Chow diets were fed to white shrimp, and detritus and AF-1 diets were fed to white and brown shrimp.

Although the two artificial diets were comparable in chemical analyses, the overall digestibility of AF-1 (55%) was low compared with the Chow. According to Brazka (in Edmondson and Winberg, 1971), this indicates either a "specific barrier" in digestion of the diet or superfluous feeding. Of the components of AF-1, the shrimp meal, because of its high chitin content, may be the cause of the inefficiency of assimilation.

In general, lipids and proteins were digested with a higher efficiency than total organic assimilation while carbohydrate assimilation lagged. The main exception to these generalizations was the detritus protein, which was assimilated with an efficiency of 75% compared to 85% for U'. Bacterial cell walls reportedly account for from 10 to 40% of the dry weight of the cells and are composed of as much as 75% protein (Pelczar and Reid, 1965). The lower digestibility of detritus protein may be due to an enzymatic inability to attack the compacted cell wall protein. However, the results for this diet are not clear since the assimilation efficiencies for the specific organic moieties are all equal to or lower than U'. This implies either that (1) the correction factors and standards employed were not representative of the organic moieties present in the samples or that (2) an unmeasured fraction of the total organic weight was assimilated with a higher efficiency than the total organic matter. These difficulties are inherent in any general analysis of this type and indicate the necessity for care in interpretation of results.

For protein digestibility our results are considerably higher than those of Nose (1964), who used a chromium oxide tracer to study assimilation of protein by *Penaeus japonicus*. On a diatom diet he found a U'_p of 62.5%; on *Ulva*, a green alga, a maximum of 30%. The experiments are difficult to compare with ours because Nose also found a direct proportionality between nitrogen content of the diet and U'_p. Assimilation efficiency of protein increased with diet nitrogen. His diatom and *Ulva* diets were 1.36 and 1.64% nitrogen, respectively, compared to our analyses of 7.6% in *Cylindrotheca fusiformis*. At the diet nitrogen concentration we measured one would expect, using the proportional-

ity Nose demonstrated, a U'_p of about 80% compared to our observed value of 92%. Thus his low values for protein assimilation on plant diets may have been a function of the low nitrogen analysis of the food rather than an inherent inability of shrimp to digest plant proteins efficiently.

Feeding Efficiency

Feeding efficiency (grams assimilated per gram dry weight of particulate material ingested) is presented in Figure 1 and Table 5. As is demonstrated by the figure, the magnitude of the assimilation efficiency of an organic moiety itself may be misleading, as its nutritive value depends not only on digestibility but also on its concentration in the food. For instance, in the diatom diet the lipids were assimilated with an efficiency of 99%, but the feeding efficiency was only 19% (when expressed as milligrams per milligram of food × 100). Furthermore, although in this diet the lipid fraction was the most readily assimilated, twice as much protein as lipid was assimilated per unit dry weight ingested. Also although the digestibility of AF-1 carbohydrates was the lowest of the four diets ($U'_{CH_2O} = 49\%$), feeding efficiency for carbohydrates was higher than from either the detritus or the diatom because of the high carbohydrate concentration in AF-1. For the defined diets feeding efficiency parallels U' because of their high and comparable ash-free dry weights.

TABLE 5.—Feeding efficiency—the assimilation of total organic weight, protein, lipid, and carbohydrate per milligram dry weight of diet ingested.

Diet	Total organic wt A	Proteins A_P	Lipids A_L	Carbohydrates A_{CH_2O}
	μg	μg	μg	μg
Diatom	740	440	190	34
Detritus	680	240	170	70
AF-1	450	210	56	97
Chow	710	390	35	190

Minimum Rates of Net Assimilation

In tests with *C. fusiformis* and Trout Chow diets, fecal pellets were recovered quantitatively over 36- and 12-hr feeding periods, respectively. Because a small but undetermined amount of fecal material was lost, the fecal release rates reported for these diets are minimal. As is shown in Table 6, defecation of shrimp when fed

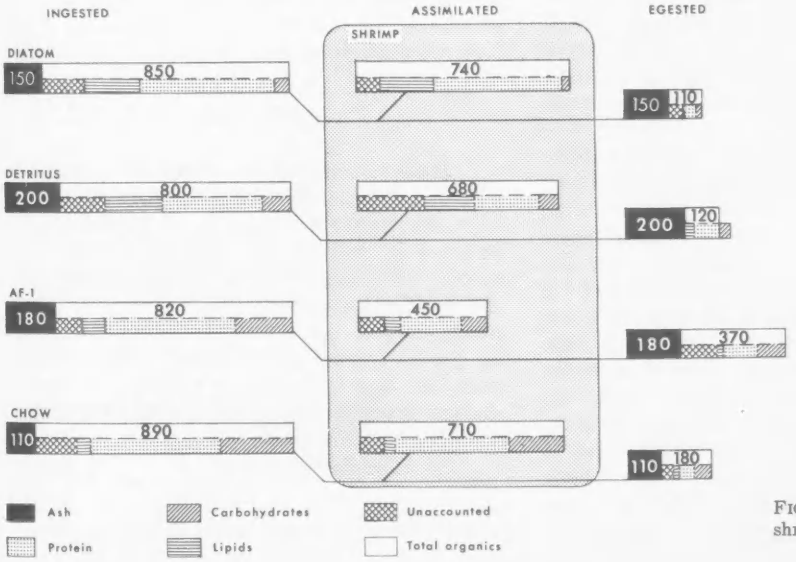

FIGURE 1.—Organic budget of shrimp fed on defined diets.

TABLE 6.—Minimum fecal release rates[1] of *Penaeus setiferus* fed on *Cylindrotheca fusiformis* and Chow.

Diet	Fecal release rate	Dry wt shrimp	Percent organic wt shrimp	Fecal release rate
	mg/hr	*g*	*%*	*mg/g organic shrimp/hr*
Diatom	5.79	5.09	83	1.3
Chow	9.06	3.15	83	3.4

[1] Calculations give minimum fecal release rates because some small loss of feces may have occurred.

on *C. fusiformis* proceeded at a minimal rate of 1.3 mg dry weight per gram organic weight of *P. setiferus* per hour. With the Chow, the release rate was more rapid, 3.4 mg hr^{-1}.

The minimal fecal release rates were employed to determine the rates at which total organic assimilation and assimilation of organic moieties occurred. These values (Table 7) reflect all three assimilation parameters, that is, digestibility, concentration in the food, and ingestion rate. The similarity in digestibility and total organic and protein composition of the two diets (see Figure 1) was obscured by the higher ingestion rate on the Chow. When viewed in time, net assimilation of organic material proceeded more than twice as fast on the Chow as on the diatom.

The protein assimilation rate followed a pattern similar to the rate of assimilation of total organic material; however, because of the high Chow carbohydrate analysis, sugars were assimilated more than 13 times as fast from the Chow than from the diatom. Conversely, even though ingestion of the diatom diet was relatively slow, its high concentration of easily digested lipids resulted in a faster assimilation of lipids than from the Chow.

We have reported assimilation rates in terms of the organic content of the feeding penaeids so that these rates are indicative of rates of replenishment. Johannes and Satomi (1967) reported the rate of net assimilation of *Nitzschia closterium* by *Palaemonetes pugio*, the grass shrimp, as 1.3 mg organic carbon per gram dry weight *P. pugio* per hour. This is somewhat lower than the rate we measured for *Penaeus setiferus* on *C. fusiformis* (2.1 mg oxidizable carbon per gram dry weight per hour). Johannes and Satomi employed quantitative recovery of food and feces rather than the ratio method.

TABLE 7.—Minimum rates of ingestion, net assimilation, and egestion of total organic weight, protein, lipid, and carbohydrate per gram organic weight *Penaeus setiferus*.

Diet	Organic moiety	Ingested *I*	Assimilated (net) *A*	Egested *N*
		mg hr^{-1}	*mg* hr^{-1}	*mg* hr^{-1}
Diatom	Total organic wt	4.3	3.7	0.6
	Protein	2.4	2.2	0.2
	Lipid	0.92	0.91	0.01
	Carbohydrate	0.29	0.17	0.12
Chow	Total organic wt	10.5	8.4	2.1
	Protein	5.3	4.6	0.7
	Lipid	0.53	0.41	0.12
	Carbohydrate	2.9	2.2	0.7

The rate of organic assimilation is not necessarily proportional to the rate of incorporation into body tissue. However, for an omnivore feeding on a richly diverse flora and fauna, mutual compensation should prevent the nutritional imbalance of any specific food from exerting a profound effect (Provasoli, Shiraishi, and Lance, 1959). The data make clear the distinction between digestibility (U') and assimilation rate. The latter is a function of both U' and ingestion rate. A rapid ingestion rate can compensate for low digestibility. For example, Meyers[6] has preliminary growth experiments which suggest that the growth rate on AF-1 is high although U' on this diet is low (Table 4).

ALGAL MAT

In order to estimate the ability of the shrimp to graze a naturally occurring food material, white shrimp were allowed to feed individually on the algal mat coating *Spartina alterniflora* culms. This mat consisted mostly of diatoms and filamentous green algae growing on and among the red algae *Polysiphonia* and *Bostrichia*. Such communities are found on the bottommost foot of the streamside *Spartina* in many shallow brackish water bays along the southeastern Louisiana coast.

[6] Personal communication, Dr. Samuel P. Meyers, Louisiana State University, Baton Rouge, La.

Penaeids were able to remove sections of the algal mat from the surface of *S. alterniflora* with either the mandibles, or the mandibles and the first and second walking legs. These sections were then rotated in the mandibular area by the maxillipeds. Rejection of uningested particles occurred in the mandibular region. At no time was regurgitation of particles entering the proventriculus observed.

Despite rejection of portions of the mat, the concentration of oxidizable carbon in the algal mat presented to each shrimp was employed as an approximation of oxidizable carbon ingested. Thus, in this test we were unable to account for selection. Table 8 shows the concentration of oxidizable carbon occurring in the mat and feces.

TABLE 8.—Net assimilation efficiencies of individual *Penaeus setiferus* fed on algal mat.

Shrimp length	Algal mat oxidizable carbon	Feces oxidizable carbon	[1]U'
	Dry wt[2]	Dry wt	
mm	%	%	%
24	24	8.0	80
30	25	9.4	77
32	22	11	64
35	20	11	56
36	22	12	62
37	26	8.6	81
40	22	14	52
42	29	16	66
44	31	13	76
Mean			68
Standard deviation	3.6	2.6	10.7

[1] A ratio of organic weight to oxidizable carbon of 2 was chosen to convert oxidizable carbon to total organic weight.
[2] Individual values recorded have a coefficient of variation of 10%.

Assimilation efficiency ranged from 52 to 81%, with a mean of 68%. The feeding efficiency (Figure 2) was 33%. Thus, digestibility of the algal mat appears to be lower than that of two of its constituents, i.e., *C. fusiformis* and detritus. The lower (68%) *U'* for the algal mat compared to the defined diets may be explained by the following considerations. First, the green and red algae present in the mat have cellulose cell walls which are probably not digestible, or may be more resilient to trituration, by the shrimp. Second, the ash content of the mat was about 50%, and Conover (1966b) has reported an inverse relationship between ash content and digestibility of various algal diets ingested by *Calanus hyperboreus*. A third possibility concerns the rejection of portions of the mat as a means of selection. The occurrence in the rejected material and in the feces of the same algal species indicated that rejection was not a method of selection for specific organisms. However, the rotation of the detached mat in the mandibular area close to the excurrent respiratory stream appeared to result in removal of adherent silt. If this observation is valid, the organic fraction in the algal mat as it occurs on *Spartina* would be lower than that of the ingested material, and efficiencies of net assimilation and feeding would have been underestimated in this study.

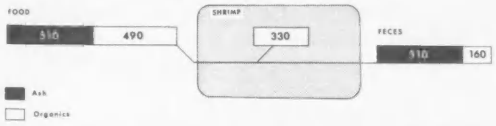

FIGURE 2.—Organic budget of shrimp fed on algal mat.

CONCLUSIONS

The results of this study and others begin to form a picture of the feeding process in shrimp, which is still far from complete, but does explain some of the observed phenomena. We describe this process for a shrimp feeding on an algal-microbial community such as that described above, not as a definitive statement but as a hypothesis for further testing.

A portion of the mat is torn off by the first and second walking legs and passed to the maxillipeds. Rotation of the mat in the proximity of the excurrent respiratory stream results in washing most of the silt away from the periphery of the mat. Once cleaned, the peripheral area is torn off by the mandibles and ingested. Thus selection for organic material occurs. Continued rotation of the mat entangles the inner algal filaments and silt into a ball. This knotting of the filaments impedes further silt removal. At this point, the uningested portion is rejected.

Ingested material enters the proventriculus where it is ground between the teeth of the gastric mill and forced through the filter press into the digestive gland (Dall, 1967). Passage of the ingested material through the proventriculus is governed in part by the time required for this trituration. As the digestive gland fills, ingestion slows. Thus the ingestion rate is governed by the filling of the digestive gland which is in turn regulated by the time required to render the food small enough to enter this organ. In this respect the shrimp is viewed as a conservative grazer, ingesting no more than it can effectively assimilate at one time (see Corner and Cowey, 1968, on the question of superfluous feeding.)

The assimilation of an organic moiety is a function of (1) the activity and concentration of the digestive enzymes of the shrimp and (2) the form of the moiety in a specific diet. Differences in rates of assimilation of different organic moieties indicate that lipases and proteinases are more active in the shrimp's digestive processes than are carbohydrases. The form of the moiety determines its susceptibility to catalytic attack. For instance, the diatom lipids were assimilated almost entirely (99%); whereas assimilation efficiency of the detritus lipids, which occurred at about the same concentration in the diet, was 86%. We suggest that lipids in the diatom occur primarily as oil droplets in the cell and are easily leached and attacked by lipolytic enzymes. Incorporation of the lipids into structural materials such as cell membranes in bacteria could make them less accessible by enzymes and reduce assimilation efficiency. For structural components of a diet, then, assimilation efficiency would be related to the degree of maceration or trituration of the food.

Material not entering the digestive gland passes from the proventriculus to the intestine to be voided at the anus. The physical requirement in the shrimp for material to occupy the space in the proventriculus above the filter press probably places a mechanical limit upon its assimilation efficiency.

The results suggest three generalizations concerning the type of diet shrimp may be expected to feed on in the natural environment. (1) Juvenile shrimp exhibit a high and comparable assimilation efficiency on a variety of plant and animal materials. (2) Proteins and lipids are, in general, assimilated more efficiently than carbohydrates. (3) Rates of assimilation on different material vary, and this variability is considered to be related to how rapidly the diet can be ground and filtered for assimilation. These generalizations show the shrimp to be a true omnivore in the sense that it is able to assimilate a wide variety of foods. The most digestible food is high in protein and lipids, low in carbohydrates.

Since the animal occurs seasonally in high concentrations in the marsh, its natural diet must be present in large volumes and must be rapidly replenished. Data from our laboratory[7] indicate that the benthic meiofaunal biomass in the Louisiana saline bays is insufficient to comprise a major volume of the shrimp's diet. On the other hand, the rates of production of detritus from the marsh grass *Spartina*, and of the periphyton and benthic communities, have been found to be high (Kirby, 1971; Stowe et al., 1971; Pomeroy, 1959). Thus, of the naturally occurring foods, the benthic algal communities and the detrital microbial communities on dead *Spartina*, because of their rapid turnover rates, appear to be the most likely sources.

ADDENDUM

An excellent article by Forster and Gabbott (1971) was published during final revision of this publication. They investigated the nitrogen and carbohydrate assimilation of certain commercial foodstuffs by *Palaemon serratus* and *Pandalus platyceros*. Nitrogen assimilation of the different diets varied from 80 to 95% whereas the assimilation of simple carbohydrates varied from 66 to 102%. Thus the nitrogen assimilation efficiencies reported in our paper agree with their findings while our carbohydrate assimilation efficiencies are lower.

[7] H. J. Bennett, Louisiana State University, Baton Rouge, La. (Unpublished.)

The primary question raised by Forster and Gabbott for our results is the reliability of Conover's ratio method. They were unable to account for 29 to 40% of the ash, and were not certain whether this was assimilated or lost to solution. With the ratio method assimilation of ash leads to underestimation of assimilation efficiency. For such a case the corrected assimilation efficiency ($U'_{correct}$) is given by the equation:

$$U'_{correct} = U'/100 + (A_u/A_f)\,[E'(1 - F')/F'(1 - E')] \times 100$$

where A_u/A_f is the fraction of ash assimilated. Similarly for U'_X the corrected value is found by the same equation except that the second term is also multiplied by r_n/r_i. From these equations it can be seen that the error incurred by failure to correct for assimilation of ash varies inversely with the ash content of the food and directly with the organic content of the feces. Thus errors are magnified when U' is low. If we assume that the upper limit of ash assimilation reported by Forster and Gabbott applied to our studies, the error in our U' values would be less than 10% for all diets except AF-1, which would have been in error by 35%. Similarly, high U'_X values would have small errors, low values relatively large errors.

We consider it likely that the high apparent ash assimilation of Forster and Gabbott are related to the organism used and the experimental conditions. They point out that loss of ash may have occurred through regurgitation and excretion. These parameters would be important when shrimp are fed for a short period (15 min) and feces collected subsequently over a long period (20 hr). On the other hand in our tests we observed no regurgitation, the shrimp fed continuously, and feces were collected about every 2 hr. These conditions should minimize ash loss.

ACKNOWLEDGMENTS

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NOTES

GROWTH AND FOOD CONVERSION OF RAINBOW TROUT REARED IN BRACKISH AND FRESH WATER

Although brackish water culture of rainbow trout (*Salmo gairdneri* Richardson) has been practiced in other countries for years (Awakura, 1962; Awakura, Shibata, and Honma, 1962; Sato, 1965; Jensen, 1967), few attempts have been made to culture this euryhaline species in brackish water in the United States (Leon, 1970). The following study was designed to study the growth, food conversion, and survival rates of rainbow trout reared from fingerling to market size in brackish and fresh water.

Materials and Methods

Six 1.8-m diameter round fiber glass tanks with a water depth of 0.6 m were used as experimental culture tanks (Andrews et al., 1971). Fresh water from a deep well (22°C) or brackish water (25-30‰) from the Skidaway River, Savannah, Ga., was pumped into each tank through flow control nozzles at a rate of 19 liters/min (1.3 hr/exchange). Since the temperature of the brackish water varied and the experimental tanks were located out-of-doors, water temperatures were not controlled.

Four experimental tanks were stocked with rainbow trout averaging 60 g each at an initial density of 7.2 kg fish/m^3, and two were stocked at a density of 14.4 kg fish/m^3. Fish in two of the tanks containing 7.2 kg/m^3 and the tanks containing 14.4 kg/m^3 were acclimated to brackish water by gradually changing the fresh to brackish water ratio of incoming water. Figure 1 shows the changes in salinity during the 9-day acclimation period.

Each group was fed a commercial pelleted trout feed[1] twice daily according to Leitriz's feeding table (Oshima, 1968). The entire population of each tank was weighed and counted monthly. Temperatures, ammonia, salinity, and dissolved oxygen levels were determined biweekly. Ammonia levels were below 0.3 ppm and oxygen concentrations were above 7.0 ppm throughout the experimental period. After 16 weeks (December 4, 1970-March 26, 1971) the experiment was terminated. Growth data was tested for statistical significance by the method of Duncan (1955).

Results and Discussion

Acclimation to brackish water

A survival rate of 99.5% was obtained in the two groups acclimated to brackish water during the 9-day period and the following 10 days in which salinity was 30‰. These results are in contrast to a previous report that over 40% mortality was obtained when rainbow trout weighing approximately 60 g each were adapted to 30‰ salinity (Oshima, 1968).

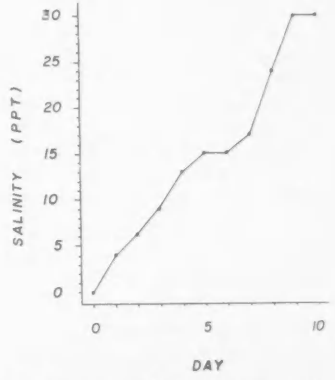

FIGURE 1.—Changes in salinity during the 10-day period in which the rainbow trout fingerlings were acclimated to brackish water.

[1] Donated by Agway, Inc., Syracuse, N.Y.

In a pre-experiment test, 60-g trout were gradually adapted from fresh water to 30‰ salinity within a 1-day period with a mortality of 5%.

These results indicate that a gradual change from 0 to 30‰ salinity over a 10-day period can be accomplished with low mortality. Since other studies have indicated that larger fish are more easily adapted to higher salinities than smaller fish (Awakura, 1962; Sato, 1965), this conclusion only holds for the 60-g fish.

Growth, survival, and food conversion data

Growth curves for the three experimental groups are shown in Figure 2 along with the average water temperatures for the corresponding period. During the first 5 weeks of this experiment when the growth rates of all groups were similar, temperature differences were not as large. Once temperature differences occurred, growth rates were affected. The final average individual weights (256 g) were significantly higher ($P < 0.05$) in the freshwater groups which were maintained at near constant temperature (averaging 21.3°C) than in the colder saltwater (13.5°C) groups (217 g in the low density group and 176 g in the high density group). The average final density (Table 1) was significantly greater ($P < 0.05$) from the highest stocking density tanks in brackish water (Group 2) than from the lower density brackish water (Group 1) and freshwater (Group 3) tanks.

Food effiiciency and survival were best in the lower stocking density brackish water tanks (Group 1) and poorest in the freshwater tanks (Group 3). A gradual mortality of one or two fish daily was observed in the freshwater group which was maintained at temperatures in excess of the optimum temperature for rainbow trout.

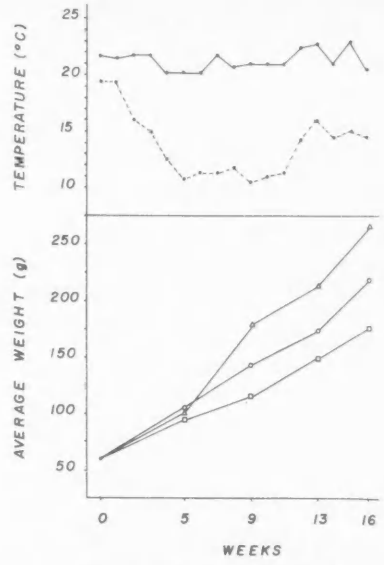

FIGURE 2.—Water temperatures and growth curves from an experiment in which rainbow trout were reared in fresh and brackish waters. The solid and broken lines represent temperatures for the freshwater and brackish water groups, respectively. The triangles represent average weights of the fish in the freshwater group, and the circles and squares represent average weights for the low and high density brackish water groups, respectively.

Temperature had a greater effect on growth, food conversion, and survival than did salinity. The freshwater group maintained at approximately 21°C grew faster than the brackish water group on the individual weight basis, but had

TABLE 1.—Experimental data from the entire 16-week growing period (December 4, 1970-March 26, 1971).

Group	Initial density	Average salinity	Average temperature[1]	Final density[2]	F.C.R.[3]	Percent survival
	kg/m³	‰	°C	kg/m³		
1	7.2	28 ± 0.6	13.5 ± 3.2	24.0 a	1.8	98
2	14.4	28 ± 0.6	13.5 ± 3.2	42.6 b	2.1	93
3	7.2	0	21.3 ± 1.3	27.2 a	2.3	87

[1] Brackish water (incoming) was pumped from Skidaway River which varied in temperature while fresh water was direct from a well and at a constant temperature (22°C).
[2] Values follow by the same letter are not statistically different ($P > 0.05$).
[3] Food conversion ratio (grams feed/gram gain).

a poorer food conversion efficiency and survival rate. The lower survival rate (87%) of this group resulted in a total production (final density) only slightly greater than the saltwater group stocked at the same density.

A faster growth rate, better survival, and better food conversion were obtained at the lower stocking density brackish group thus demonstrating the effects stocking density has on these variables. The fact that oxygen was over 7 ppm in all groups throughout this experiment indicates that stocking density and not oxygen stress accounted for this reduction in performance.

Conclusions

The fact that temperature was not constant in all groups precluded a conclusive comparison of the performance of rainbow trout in brackish and fresh water. Nevertheless, the following conclusions can be made from these experimental data:

1. Rainbow trout were converted from fresh to 30‰ salinity in a period of 9 days and were reared to market size at this salinity.
2. Trout fingerlings averaging 60 g each were reared to 266 g in 21°C fresh water with a rapid individual growth rate and an acceptable survival and food conversion rate.
3. Survival and growth rates and food efficiencies were excellent for trout reared in brackish water at an average temperature of 13.5°C.

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THE AMOUNT OF SPACE AVAILABLE FOR MARINE AND FRESHWATER FISHES

Cohen (1970) has presented rather careful estimates of the total number of fish species in the world and in each of eight ecological groupings. He found that an "astonishingly high percentage" of bony fishes live in freshwater habitats. According to Cohen's analysis, 41.2% (8,275 species) of all fish species live in fresh water (includes both primary and secondary freshwater fishes). He indicates that this high percentage must reflect the degree of isolation possible in freshwater environments and refers to the great variety of habitats and ecological niches in fresh water and also along tropical shores.

The great number of freshwater fish species becomes even more striking if the volume of fresh water in the world is compared to the volume of the oceans. Indeed, the mode of speciation and the structure of the niche appear highly divergent between the two environments. The oceans account for 97% of all the water in the

world whereas the amount of fresh water in lakes and rivers (that which would be available as fish habitat) approaches an almost negligible percentage—only 0.0093% of the world's water (van Hylckama, 1971) (Table 1). In this sense then, 41.2% of all fish species live in less than one one-hundredth of one percent of the available water. Table 2, which is based on Cohen's (1970) data and on the data presented in Table 1, shows the great disparity between freshwater and marine environments in terms of the number of species per unit volume of water. The calculations show that there are about 113,000 km³ of water per marine species but only about 15 km³ for each freshwater species, or approximately a 7,500-fold difference. It is, of course, true that a species does not occupy a particular parcel of water to the exclusion of other organisms; nevertheless, it seems conceptually possible and without undue loss of reality to consider that each species has available a certain volume of water which it can occupy. It is known, too, that marine habitats vary greatly from high diversity in tropical shore and coral reef regions to low diversity in open ocean areas (including the deep ocean which constitutes most of the volume of the oceans and in which numbers and biomass greatly decrease with depth). Shore and shelf fishes have about 290 km³ of water per species compared with about 1,000,000 km³ for pelagic species (Table 2), or approximately a 3,400-fold difference. If the slope and deep-sea benthic species are added to the pelagic figure, the unit volume of water per species beyond the continental slope is reduced to about 500,000 km³, which is still a relatively very high figure. The volume of water per species of marine shore and shelf fishes is higher than the freshwater figure by about 20× (290 km³ vs. 15 km³). This reflects the similarity in the degree of partitioning in these two regions. Perhaps the number of species per unit volume in the richer tropical reefs exceeds that in a large percentage of freshwater habitats. Also, some marine habitats which are superficially similar to certain freshwater habitats may be expected to have species densities comparable to their freshwater counterparts. Examples might be 1) the deep parts of oceans and lakes (low species density), 2) kelp beds in coastal waters and the vegetated zones of lakes (high species density). It is the open ocean with its broad expanse and great depth that contributes most to the overall very low concentration of species and numbers (discussed below) of marine fishes.

TABLE 1.—Supply (km³) of water in the world available as fish habitat (from data by van Hylckama (1971)).

Item	Volume	Percent of total
Total water in the world	1,360,000,000	100.0
World oceans	1,320,000,000	97.0
Freshwater lakes	125,000	0.0092
Rivers (at any one time)	1,300	0.0001

(remainder of total is ice, groundwater, atmospheric water, etc.)

TABLE 2.—Volume (km³) of water available per species in various habitats.

Type of species	Volume/species
Total marine	113,000
Marine shore and continental shelf to 200 m	290*
Marine pelagic beyond continental shelf	1,000,000
Marine pelagic + continental slope and deep sea benthic	500,000
Total fresh water	15

* The volume of water over the continental shelf was calculated by considering that the shelf underlies 7.5% of the ocean surface (Emery, 1969) and that the average depth over the shelf is about 100 m or 2.5% of the ocean's average depth of 4,000 m.

While it is difficult to estimate the number of fish species in an environment, it is much more difficult to even speculate on the number of individuals per species in either marine or freshwater regions. Gadgil[1] arrived at a figure of 4×10^9 as the average number of individuals per fish species based largely on marine data. Certainly, different marine habitats support widely differing numbers of fishes. Pelagic species such as certain anchovies may attain population levels of 10^{12} whereas some rocky shore species may be several orders of magnitude lower in total numbers, perhaps near 10^6 individuals per species. A figure in the middle of the above two estimates would be 10^9, and in this discussion I have considered 10×10^9 to be the average number of individuals per species in the sea. It

[1] Gadgil, M. On numbers of fish. (Unpublished manuscript) Biology Department, Harvard University, Cambridge, Mass. Present address: Maharashtra Association for the Cultivation of Science, Agarkar Road, Poona 4, India.

is fairly certain, I think, that there are fewer individuals per species among freshwater fishes than among marine fishes. The degree of difference in abundance is, however, difficult to estimate or even imagine. There are some very abundant freshwater species such as certain clupeids and cyprinids, but some are quite rare, most notably the desert cyprinodontids of the southwestern United States which may exist only in the thousands or even hundreds per species.

Two values were used for the average number of individuals per freshwater species—a high value (10×10^9), the same as the figure for marine species, and a low value (10×10^6) which I think is a conservative minimum. A range of values conveys more information in comparing the marine and freshwater situations. The calculations in Table 3 show that marine fishes have $10\times$ to $10{,}000\times$ more space available per individual than freshwater forms, depending upon which freshwater value is chosen. If the lower freshwater figure (10×10^6) is more nearly correct, then the degree of isolation and habitat partitioning in fresh waters becomes even more strikingly apparent. On the basis of total numbers per species, the difference per unit volume between the oceans and fresh water is only 10-fold whereas on the basis of species per unit volume, the difference is approximately 7,500-fold.

TABLE 3.—Volume (km^3) of water available per individual fish in the sea and in fresh water.

Type of species	Number of species	Individuals/ species	Volume/ individual
Marine	11,675	10×10^9	1.1×10^{-5}
Fresh water (1)	8,275	10×10^9	1.5×10^{-9}
Fresh water (2)	8,275	10×10^6	1.5×10^{-6}

The above disparity would seem to be related not only to the degree of isolation but to the relative levels of productivity and biomass in the two environments. Table 4 shows net primary productivity and plant biomass estimates for three major ecosystems: 1) lake and stream, 2) continental shelf, and 3) open ocean. Net primary productivity per unit area in fresh water is about $1.5\times$ to $4\times$ as high as in the sea, and plant biomass per unit area in fresh water is about $2\times$ to $7\times$ as high as in the sea. These figures are perhaps not in great discord with the estimate above that $10\times$ as many fishes occur per unit volume in fresh water as in the sea.

TABLE 4.—Net primary productivity and plant biomass per unit area in three major ecosystems (from data compiled by Whittaker (1970)).

Major ecosystem	Net primary productivity	Biomass
	dry g/m²/year (mean value)	*dry kg/m² (mean value)*
Lake and stream	500	0.02
Continental shelf	350	0.01
Open ocean	125	0.003

These data serve, I believe, to illustrate the quite astounding difference between the amount of space available for freshwater and marine fishes. As Cohen (1970) has emphasized, the calculations also make apparent the need for increased research on freshwater fishes since their habitats are being rapidly modified. In terms of conservation and economic policies, important studies should include those that compare numbers of species and individuals in different local and regional environments in relation to levels of productivity and other factors.

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A SYSTEM FOR COLLECTING LARGE NUMBERS OF LIVE POSTLARVAL PENAEID SHRIMP[1]

Acquiring large numbers of small marine organisms for experimental or commercial purposes is often hampered by inefficient methods. Means for concentrating organisms and separating desired species from the rest of the catch can be particularly troublesome problems.

For commercial shrimp culture and related research, a system is needed whereby large numbers of postlarval shrimp can be efficiently caught, separated, and held alive in a healthy condition. The shrimp of greatest interest for pond culture include the tropical and subtropical species whose habit of entering estuaries during larval stages and remaining there for several weeks makes them accessible in large numbers to various collecting methods. Two general methods are presently employed to collect shrimp for culture. Postlarvae are impounded in the Orient by manipulating tidal flow with sluice gates built into the dikes of ponds (Walford, 1958). This method, however, also impounds undesirable species that enter with the small shrimp. Fishermen of the Philippine Islands catch shrimp larvae by immersing bundles of grass at the edges of mangrove thickets and periodically removing the attached postlarvae with a dip net, or by dipping a triangular net into the water (Caces-Borja and Rasalan, 1968). These methods are time-consuming, and the number of postlarvae caught varies greatly among localities; often catches are too small to provide stock for a successful crop.

The objective of this study was to develop more efficient methods for collecting and separating large numbers of postlarval brown shrimp, *Penaeus aztecus*. Postlarvae of this species immigrate through tidal passes on flood tides from February through September along the Texas coast with peak abundance occurring during late winter and early spring (Baxter and Renfro, 1966). The postlarvae occur in great numbers near the surface, especially in the more shallow areas (Duronslet, Lyon, and Marullo, in press) and are about 11 mm in total length and 1 mm in diameter at immigration.

Description of Equipment

The collecting system, designed for use on a 13-m vessel, is shown in Figures 1 and 2. The telescoping outriggers consist of a pipe frame attached to the vessel and pipe extensions which slide inside the frame. The frame itself was constructed from two pieces of 76-mm (outside diameter) galvanized pipe bolted side-by-side to the top of the cabin. The extensions were 51-mm (outside diameter) galvanized pipe. Holes were drilled in the pipes so that each could be extended 2.4 m and secured with a steel pin.

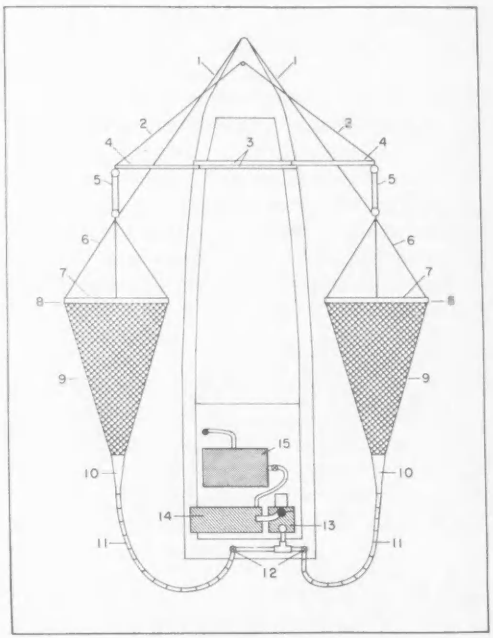

FIGURE 1.—Schematic drawing of collecting system: 1 - bow bridles; 2 - staywires; 3 - outrigger frame; 4 - outrigger; 5 - double block; 6 - net bridle; 7 - trash screen; 8 - net frame; 9 - net; 10 - funnel; 11 - suction hose; 12 - screw valve; 13 - pump; 14 - sorting box; 15 - holding tank.

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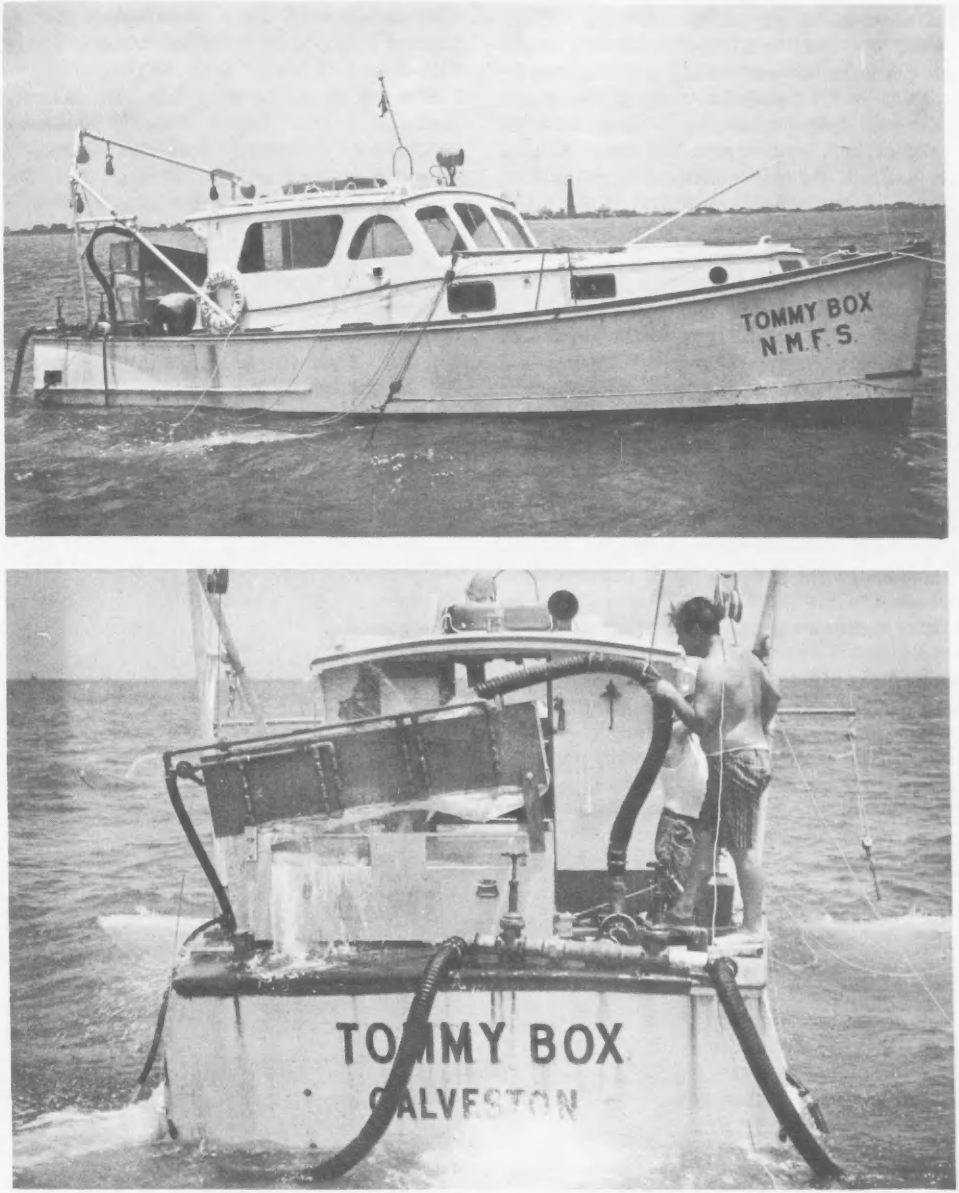

FIGURE 2.—Collecting system in operation on flood tide.

Net frames, 1.2 by 2.4 m, were constructed of 3-mm flat steel reinforced with 6-mm iron rods. Six U-bolts were welded to the frame for the attachment of stainless steel cables which bridled each frame to a double block bolted to the end of each outrigger. The trash screens were made of 6.4-cm square mesh galvanized hardware cloth soldered onto galvanized metal frames which were bolted to the net frame. The nets were fabricated from nylon netting (169 meshes per square inch) measuring 3.7 m in length and patterned so that the seams ran from the corners of the metal frame to the aluminum rings. The rings were attached with bayonet fittings to the collecting funnels. Both the mouth and tail of the nets were reinforced with cotton duck and fitted with brass grommets so that the nets could be laced on the frames and rings.

The collecting funnels were made with 3-mm flat stock aluminum and were 90 cm long (30 cm outside diameter at the mouth and 7.5 cm inside diameter at the tail). A 15-cm nipple was welded to the posterior end where the suction hose from the pump was attached, and a 10-cm flat band was welded to the mouth of the funnel. L-shaped slots were cut in the leading edge of the band. These slots were spaced so that countersunk bolts in the aluminum ring of the net could be inserted and rotated for quick attachment of the net to the funnel.

The self-priming, centrifugal, solids handling pump ("Crown" model PO3LB, Construction Machinery Company, Waterloo, Iowa[2]) was powered by the winch power shaft (Figure 3). In turn, the power shaft was controlled by a small hydraulic motor which allowed regulation of pumping speed. Water volume output could be controlled from 0 to 180 gal/min.

The pump intake pipe was attached to a 7.6-cm (outside diameter) PVC (polyvinyl chloride) tee. A reinforced rubber hose led from each side of the tee to the respective funnel, and a brass screw valve was incorporated in each hose so that we could pump from either or both nets.

The sorting box (Figures 3 and 4) was designed so that the smallest animals caught would be retained and the larger ones discarded. This was accomplished by pumping the catch from the nets onto three sets of sloping screens. A water-jet system was used to keep the animals

[2] Use of trade names in this publication does not imply endorsement of commercial products by the National Marine Fisheries Service.

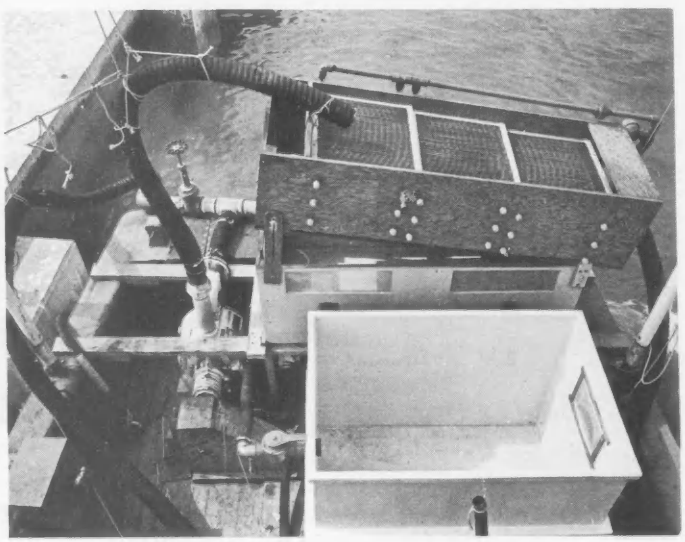

FIGURE 3.—Pump, sorting box, and holding tank.

separated and moving down the screens. The screen frame and the catch box located beneath the screens were made with 19-mm marine plywood. One end of the screen frame was hinged and could be set at the slope providing maximum sorting efficiency. To accommodate excess water, six overflow windows around the top edge of the catch box were screened with fine-mesh netting. The catch box drain emptied into a 145-gal fiber glass holding tank having screened overflow windows (Figure 3).

The 54- by 51-cm screens were constructed of brass welding rods and flat stock aluminum. The rods were cemented in place at both ends along the aluminum strips with liquid solder cement. Excess cement was ground off, and another aluminum strip was bolted to each end, thus sandwiching the brass rods between aluminum strips. Three layers of screens were installed in the frame with each layer having three screens fitted end-to-end so that the rods ran parallel with the long axis of the frame. The average openings between rods for the screen layers were 3, 2, and 1½ mm.

FIGURE 4.—End view of sorting box.

Water-jet pipes were inserted through the walls of the screen frame 5 cm below each screen with two pipes per screen (Figure 3). The pipes were perforated with 2-mm holes spaced 25 mm apart to form the water jets. The force of the jets, which was supplied with water by a 25-mm gasoline-driven centrifugal pump, was controlled by a PVC ball valve on the discharge line of the pump.

Operation of System

After anchoring the vessel, the outriggers were extended, the suction hoses and cones put overboard, and the nets and frames were lowered into the water. A rope was then passed around the bow, and the ends were attached to the bridle of each net. When the nets were subsequently slacked back, the rope bridles became taut, and tidal flow forced the frames into the water (Figure 2). The solids-handling pump and the water-jet pump were then engaged and the jet heights adjusted. When the sorting box was full of water, the valve on the bottom was opened allowing the catch to flow into the holding tank.

Evaluation of System

The number of brown shrimp postlarvae caught per cruise was estimated by periodically taking 5-sec samples from the pump discharge. Twenty collection cruises were made on flood tides between March 17 and June 2, 1971 (Table 1). Numbers of postlarvae caught during individual cruises ranged from 0 to about 106,000, and the total estimated catch for all cruises was about 411,600. Mortalities associated with catching, pumping, and sorting brown shrimp postlarvae were less than 3%.

During evaluation of the system, large numbers of larval fishes and crustaceans other than postlarval brown shrimp were collected. The

more common and readily recognizable forms are listed in Table 2. Mortalities related to capture of these larvae were estimated to be less than 10%, while mortalities for subadults and adults were less than 20%. Large specimens of Atlantic cutlassfish, sea catfish, Atlantic croaker, Gulf menhaden, and the blue crab were passed through the pump with little damage. The sorting box was effective in removing all animals and trash larger than 1.5 mm in diameter, or about 95% of the larval fishes caught. Postlarvae retained in the trash were less than 10% of the total number of postlarvae caught. Larval stages of the blue crab were not effectively separated, however, and were voracious feeders on postlarvae.

This system was efficient in capturing and sorting large numbers of postlarval shrimp and, by adjusting the widths of the sorting screens, can be used to catch and sort most small animals as they migrate through tidal passes. The pump and suction cone attachment on the tail of the nets provided a constant free flow of water which eliminated the problem of clogging or fouling as encountered with standard plankton nets. The system is not restricted to use on a boat and could be easily adapted for land-based operations from piers and platforms.

TABLE 1.—Estimated number of postlarval brown shrimp caught by date in the Bolivar Roads Tidal Pass, Galveston Bay, Tex., 1971.

Date		Fishing time (min)	Number of samples	Estimated total catch
March	17	167	8	14,400
	20	240	9	3,800
	21	50	5	3,000
	22	108	9	5,200
	23	80	6	800
	26	173	16	45,200
	27	345	16	46,200
	28	335	32	52,600
	30	465	49	65,100
	31	180	15	4,500
April	2	173	8	500
	3	150	15	5,100
	7	120	12	200
	13	155	17	9,100
	20	60	6	1,400
	21	135	13	0
	30	100	10	23,200
May	19	160	16	800
	20	220	21	106,000
June	2	90	9	24,500
Total		3,506	292	411,600

TABLE 2.—Fishes and crustaceans collected during evaluation of the system; A = abundant; O = occasional.

Scientific name	Common name	Juvenile	Adult
Anchoa mitchilli	Bay anchovy	A	O
Brevoortia patronus	Gulf menhaden	A	O
Callinectes danae	Gulf crab	O	O
Callinectes sapidus	Blue crab	A	O
Cynoscion arenarius	Sand seatrout	O	
Dysommia sp.	Eel	A	
Elops saurus	Ladyfish		A
Arius felis	Sea catfish	A	O
Gobiesox strumosus	Skilletfish		O
Hippocampus zosterae	Dwarf seahorse		O
Histrio histrio	Sargassumfish		O
Libinia emarginata	Spider crab	O	
Menticirrhus americanus	Southern kingfish	O	
Micropogon undulatus	Atlantic croaker	A	O
Monacanthus hispidus	Common filefish		A
Mugil cephalus	Striped mullet	A	
Ophidion welshi	Crested cusk-eel		O
Palemonetes sp.	Grass shrimp		A
Penaeus setiferus	White shrimp	A	A
Polydactylus octonemus	Atlantic threadfin		A
Porichthys porosissimus	Atlantic midshipman		O
Prionotus tribulus	Bighead searobin		O
Sergistid sp.		A	A
Sphoeroides nephelus	Southern puffer	O	O
Squilla sp.	Mantis shrimp	A	A
Syngnathus scovelli	Gulf pipefish	A	A
Synodus foetens	Inshore lizardfish	A	O
Trachypenaeus sp.	Brokenback shrimp	O	A
Trichiurus lepturus	Atlantic cutlassfish		A

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1) p. 1048. The left-hand curve ("Present Study") in Figure 3 is incorrectly labelled. The equation should read $W = 0.000006L^{3.183}$, not $W = 0.000017L^{3.183}$.

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